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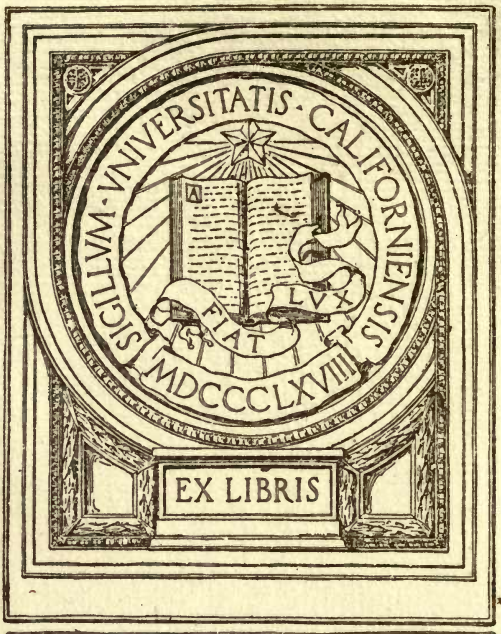
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ENGINEERING TABLES AND DATA.

BY

W. W. F. PULLEN,

Wh.Sc., M.I.Mech.E., Assoc.M.Inst.C.E.

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PREFACE.

THIS little collection of tables and data has been compiled to supply a want which has been experienced in the laboratory, the testing shop and in engineering educational work generally.

The steam table has been entirely revised, and now represents the results of the most recent researches. The compiler has received much valuable aid in the construction of this table from Mr. Gilbert Farrar, B.Sc., to whom he desires to offer his thanks. The table is given in both Fahrenheit and Centigrade units.

The few Mathematical notes in this volume have been inserted to aid in filling the gap which fickle memory is so prone to provide.

W. W. F. P.

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CONVERSION TABLE.

Circular Measure to Degrees.

Radians.	Degrees.	Radians.	Degrees.	Radians.	Degrees.
·10	5·73	·60	34·38	1·10	63·03
·11	6·30	·61	34·95	1·11	63·60
·12	6·88	·62	35·52	1·12	64·17
·13	7·45	·63	36·10	1·13	64·74
·14	8·02	·64	36·67	1·14	65·32
·15	8·59	·65	37·24	1·15	65·89
·16	9·17	·66	37·82	1·16	66·46
·17	9·74	·67	38·39	1·17	67·04
·18	10·31	·68	38·96	1·18	67·61
·19	10·89	·69	39·53	1·19	68·18
·20	11·46	·70	40·11	1·20	68·75
·21	12·03	·71	40·68	1·21	69·33
·22	12·61	·72	41·25	1·22	69·90
·23	13·18	·73	41·83	1·23	70·47
·24	13·75	·74	42·40	1·24	71·05
·25	14·32	·75	42·97	1·25	71·62
·26	14·90	·76	43·54	1·26	72·19
·27	15·47	·77	44·12	1·27	72·77
·28	16·04	·78	44·69	1·28	73·34
·29	16·62	·79	45·26	1·29	73·91
·30	17·19	·80	45·84	1·30	74·48
·31	17·76	·81	46·41	1·31	75·06
·32	18·33	·82	46·98	1·32	75·63
·33	18·91	·83	47·56	1·33	76·20
·34	19·48	·84	48·13	1·34	76·78
·35	20·05	·85	48·70	1·35	77·35
·36	20·63	·86	49·27	1·36	77·92
·37	21·20	·87	49·85	1·37	78·50
·38	21·77	·88	50·42	1·38	79·07
·39	22·34	·89	50·99	1·39	79·64
·40	22·92	·90	51·57	1·40	80·21
·41	23·49	·91	52·14	1·41	80·79
·42	24·06	·92	52·71	1·42	81·36
·43	24·64	·93	53·29	1·43	81·93
·44	25·21	·94	53·86	1·44	82·51
·45	25·78	·95	54·43	1·45	83·08
·46	26·36	·96	55·00	1·46	83·65
·47	26·93	·97	55·58	1·47	84·23
·48	27·50	·98	56·15	1·48	84·80
·49	28·07	·99	56·72	1·49	85·37
·50	28·65	1·00	57·30	1·50	85·94
·51	29·22	1·01	57·87	1·51	86·52
·52	29·79	1·02	58·44	1·52	87·09
·53	30·37	1·03	59·01	1·53	87·66
·54	30·94	1·04	59·59	1·54	88·24
·55	31·51	1·05	60·16	1·55	88·81
·56	32·09	1·06	60·73	1·56	89·38
·57	32·66	1·07	61·31	1·57	89·95
·58	33·23	1·08	61·88	$\frac{\pi}{2}$	90·00
·59	33·80	1·09	62·45		
·60	34·37	1·10	63·03		

TABLE OF NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

Sine.—To obtain the sine of an angle (say 72 deg.) look in the first or fifth columns of the following table for the angle (72 deg.) and the sine will be found opposite to it in the next column (·95106).

Cosine.—To obtain the cosine of an angle (say 72 deg.) look in the fourth or eighth column, at whose foot is degrees, and read upwards. The cosine will be found opposite to it in the second or sixth columns (·30902).

Tangent.—The tangent is found in the same way as the sine.

Cotangent.—The cotangent is found in the same way as the cosine.

Degs.	Sine.	Tangent.		Degs.	Sine.	Tangent.	
0	·00000	·00000	90	46	·71934	1·03553	44
1	·01745	·01746	89	47	·73135	1·07237	43
2	·03490	·03492	88	48	·74314	1·11061	42
3	·05234	·05241	87	49	·75471	1·15037	41
4	·06976	·06993	86	50	·76604	1·19175	40
5	·08716	·08749	85	51	·77715	1·23490	39
6	·10453	·10510	84	52	·78801	1·27994	38
7	·12187	·12278	83	53	·79864	1·32704	37
8	·13917	·14054	82	54	·80902	1·37638	36
9	·15643	·15838	81	55	·81915	1·42815	35
10	·17365	·17633	80	56	·82904	1·48256	34
11	·19081	·19438	79	57	·83867	1·53987	33
12	·20791	·21256	78	58	·84805	1·60033	32
13	·22495	·23087	77	59	·85717	1·66428	31
14	·24192	·24933	76	60	·86603	1·73205	30
15	·25882	·26795	75	61	·87462	1·80405	29
16	·27564	·28675	74	62	·88295	1·88073	28
17	·29237	·30573	73	63	·89101	1·96261	27
18	·30902	·32492	72	64	·89879	2·05030	26
19	·32557	·34433	71	65	·90631	2·14451	25
20	·34202	·36397	70	66	·91355	2·24604	24
21	·35837	·38386	69	67	·92050	2·35585	23
22	·37461	·40403	68	68	·92718	2·47509	22
23	·36073	·42447	47	69	·93358	2·60509	21
24	·40674	·44523	66	70	·93969	2·74748	20
25	·42262	·46431	65	71	·94552	2·90421	19
26	·43837	·48773	64	72	·95106	3·07768	18
27	·45399	·50593	63	73	·95630	3·27085	17
28	·46947	·53171	62	74	·96126	3·48741	16
29	·48481	·55431	61	75	·96593	3·73205	15
30	·50000	·57735	60	76	·97030	4·01078	14
31	·51504	·60086	59	77	·97437	4·33148	13
32	·52992	·62487	58	78	·97815	4·70463	12
33	·54464	·64941	57	79	·98163	5·14455	11
34	·55919	·67451	56	80	·98481	5·67128	10
35	·57358	·70021	55	81	·98769	6·31375	9
36	·58779	·72654	54	82	·99027	7·11537	8
37	·60182	·75355	53	83	·99255	8·14435	7
38	·61566	·78129	52	84	·99452	9·51436	6
39	·62932	·80978	51	85	·99619	11·43005	5
40	·64279	·83910	50	86	·99756	14·30067	4
41	·65606	·86929	49	87	·99863	19·08114	3
42	·66913	·90040	48	88	·99939	28·63625	2
43	·68200	·93252	47	89	·99985	57·28996	1
44	·69466	·96569	46	90	1·00000	Infinite	0
45	·70711	1·00000	45				
	Consine.	Contangent	Degs.		Cosine.	Contangent.	Degs.

COMMON LOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7

Log. π = ·49715. Log. 32·2 = 1·50786. Log. 981 = 2·99167. Log. 426·9 = 2·6303.

COMMON LOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	1	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Log 778 = 2·8910. Log.$_e$ = ·43429. Log. ·43429 = 1·63778. Log. 2·302528 = ·36221.

To convert to Hyperbolic Logs. multiply by 2·30258 or divide by ·43429.

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
·04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
·32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
·33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
·47	2958	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6556	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
·90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

HYPERBOLIC LOGARITHMS.

CONVERSION FACTORS—Common to Hyperbolic, 2·30258.
Hyperbolic to Common, ·43429.
Base of Hyperbolic Logarithms, 2·71828.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
1·01	·0099	1·56	·4447	2·11	·7467	2·66	·9783
1·02	·0198	1·57	·4511	2·12	·7514	2·67	·9821
1·03	·0296	1·58	·4574	2·13	·7561	2·68	·9858
1·04	·0392	1·59	·4637	2·14	·7608	2·69	·9895
1·05	·0488	1·60	·4700	2·15	·7655	2·70	·9933
1·06	·0583	1·61	·4762	2·16	·7701	2·71	·9969
1·07	·0677	1·62	·4824	2·17	·7747	2·72	1·0006
1·08	·0770	1·63	·4886	2·18	·7793	2·73	1·0043
1·09	·0862	1·64	·4947	2·19	·7839	2·74	1·0080
1·10	·0953	1·65	·5008	2·20	·7885	2·75	1·0116
1·11	·1044	1·66	·5068	2·21	·7930	2·76	1·0152
1·12	·1133	1·67	·5128	2·22	·7975	2·77	1·0188
1·13	·1222	1·68	·5188	2·23	·8020	2·78	1·0225
1·14	·1310	1·69	·5247	2·24	·8065	2·79	1·0260
1·15	·1398	1·70	·5306	2·25	·8109	2·80	1·0296
1·16	·1484	1·71	·5365	2·26	·8154	2·81	1·0332
1·17	·1570	1·72	·5423	2·27	·8198	2·82	1·0367
1·18	·1655	1·73	·5481	2·28	·8242	2·83	1·0403
1·19	·1740	1·74	·5539	2·29	·8286	2·84	1·0438
1·20	·1823	1·75	·5596	2·30	·8329	2·85	1·0473
1·21	·1906	1·76	·5653	2·31	·8372	2·86	1·0508
1·22	·1988	1·77	·5710	2·32	·8416	2·87	1·0543
1·23	·2070	1·78	·5766	2·33	·8458	2·88	1·0578
1·24	·2151	1·79	·5822	2·34	·8502	2·89	1·0613
1·25	·2231	1·80	·5878	2·35	·8544	2·90	1·0647
1·26	·2311	1·81	·5933	2·36	·8587	2·91	1·0682
1·27	·2390	1·82	·5988	2·37	·8629	2·92	1·0716
1·28	·2469	1·83	·6043	2·38	·8671	2·93	1·0750
1·29	·2546	1·84	·6098	2·39	·8713	2·94	1·0784
1·30	·2624	1·85	·6152	2·40	·8755	2·95	1·0813
1·31	·2700	1·86	·6206	2·41	·8796	2·96	1·0852
1·32	·2776	1·87	·6259	2·42	·8838	2·97	1·0886
1·33	·2852	1·88	·6313	2·43	·8879	2·98	1·0919
1·34	·2927	1·89	·6366	2·44	·8920	2·99	1·0953
1·35	·3001	1·90	·6419	2·45	·8961	3·00	1·0986
1·36	·3075	1·91	·6471	2·46	·9002	3·01	1·1019
1·37	·3148	1·92	·6523	2·47	·9042	3·02	1·1053
1·38	·3221	1·93	·6575	2·48	·9083	3·03	1·1086
1·39	·3293	1·94	·6627	2·49	·9123	3·04	1·1119
1·40	·3365	1·95	·6678	2·50	·9163	3·05	1·1151
1·41	·3436	1·96	·6729	2·51	·9203	3·06	1·1184
1·42	·3507	1·97	·6780	2·52	·9243	3·07	1·1217
1·43	·3577	1·98	·6831	2·53	·9282	3·08	1·1249
1·44	·3646	1·99	·6881	2·54	·9322	3·09	1·1282
1·45	·3716	2·00	·6931	2·55	·9361	3·10	1·1314
1·46	·3784	2·01	·6981	2·56	·9400	3·11	1·1346
1·47	·3853	2·02	·7031	2·57	·9439	3·12	1·1378
1·48	·3920	2·03	·7080	2·58	·9478	3·13	1·1410
1·49	·3988	2·04	·7129	2·59	·9517	3·14	1·1442
1·50	·4055	2·05	·7178	2·60	·9555	3·15	1·1474
1·51	·4121	2·06	·7227	2·61	·9594	3·16	1·1506
1·52	·4187	2·07	·7275	2·62	·9632	3·17	1·1537
1·53	·4253	2·08	·7324	2·63	·9670	3·18	1·1569
1·54	·4318	2·09	·7372	2·64	·9708	3·19	1·1600
1·55	·4383	2·10	·7419	2·65	·9746	3·20	1·1632

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
3·21	1·1663	3·76	1·3244	4·31	1·4609	4·86	1·5810
3·22	1·1694	3·77	1·3271	4·32	1·4633	4·87	1·5831
3·23	1·1725	3·78	1·3297	4·33	1·4656	4·88	1·5851
3·24	1·1756	3·79	1·3324	4·34	1·4679	4·89	1·5872
3·25	1·1787	3·80	1·3350	4·35	1·4702	4·90	1·5892
3·26	1·1817	3·81	1·3376	4·36	1·4725	4·91	1·5913
3·27	1·1848	3·82	1·3403	4·37	1·4748	4·92	1·5933
3·28	1·1878	3·83	1·3429	4·38	1·4770	4·93	1·5953
3·29	1·1909	3·84	1·3455	4·39	1·4793	4·94	1·5974
3·30	1·1939	3·85	1·3481	4·40	1·4816	4·95	1·5994
3·31	1·1969	3·86	1·3507	4·41	1·4839	4·96	1·6014
3·32	1·1999	3·87	1·3533	4·42	1·4861	4·97	1·6034
3·33	1·2030	3·88	1·3558	4·43	1·4884	4·98	1·6054
3·34	1·2060	3·89	1·3584	4·44	1·4907	4·99	1·6074
3·35	1·2090	3·90	1·3610	4·45	1·4929	5·00	1·6094
3·36	1·2119	3·91	1·3635	4·46	1·4951	5·01	1·6114
3·37	1·2149	3·92	1·3661	4·47	1·4974	5·02	1·6134
3·38	1·2179	3·93	1·3686	4·48	1·4996	5·03	1·6154
3·39	1·2208	3·94	1·3712	4·49	1·5019	5·04	1·6174
3·40	1·2238	3·95	1·3737	4·50	1·5041	5·05	1·6194
3·41	1·2267	3·96	1·3762	4·51	1·5063	5·06	1·6214
3·42	1·2296	3·97	1·3788	4·52	1·5085	5·07	1·6233
3·43	1·2326	3·98	1·3813	4·53	1·5107	5·08	1·6253
3·44	1·2355	3·99	1·3838	4·54	1·5129	5·09	1·6273
3·45	1·2384	4·00	1·3863	4·55	1·5151	5·10	1·6292
3·46	1·2413	4·01	1·3888	4·56	1·5173	5·11	1·6312
3·47	1·2442	4·02	1·3913	4·57	1·5195	5·12	1·6332
3·48	1·2470	4·03	1·3938	4·58	1·5217	5·13	1·6351
3·49	1·2499	4·04	1·3962	4·59	1·5239	5·14	1·6371
3·50	1·2528	4·05	1·3987	4·60	1·5261	5·15	1·6390
3·51	1·2556	4·06	1·4012	4·61	1·5282	5·16	1·6409
3·52	1·2585	4·07	1·4036	4·62	1·5304	5·17	1·6429
3·53	1·2613	4·08	1·4061	4·63	1·5326	5·18	1·6448
3·54	1·2641	4·09	1·4085	4·64	1·5347	5·19	1·6467
3·55	1·2669	4·10	1·4110	4·65	1·5369	5·20	1·6487
3·56	1·2698	4·11	1·4134	4·66	1·5390	5·21	1·6506
3·57	1·2726	4·12	1·4159	4·67	1·5412	5·22	1·6525
3·58	1·2754	4·13	1·4183	4·68	1·5433	5·23	1·6544
3·59	1·2782	4·14	1·4207	4·69	1·5454	5·24	1·6563
3·60	1·2809	4·15	1·4231	4·70	1·5476	5·25	1·6582
3·61	1·2837	4·16	1·4255	4·71	1·5497	5·26	1·6601
3·62	1·2865	4·17	1·4279	4·72	1·5518	5·27	1·6620
3·63	1·2892	4·18	1·4303	4·73	1·5539	5·28	1·6639
3·64	1·2920	4·19	1·4327	4·74	1·5560	5·29	1·6658
3·65	1·2947	4·20	1·4351	4·75	1·5581	5·30	1·6677
3·66	1·2975	4·21	1·4375	4·76	1·5602	5·31	1·6696
3·67	1·3002	4·22	1·4398	4·77	1·5623	5·32	1·6715
3·68	1·3029	4·23	1·4422	4·78	1·5644	5·33	1·6734
3·69	1·3056	4·24	1·4446	4·79	1·5665	5·34	1·6752
3·70	1·3083	4·25	1·4469	4·80	1·5686	5·35	1·6771
3·71	1·3110	4·26	1·4493	4·81	1·5707	5·36	1·6790
3·72	1·3137	4·27	1·4516	4·82	1·5728	5·37	1·6808
3·73	1·3164	4·28	1·4540	4·83	1·5748	5·38	1·6827
3·74	1·3191	4·29	1·4563	4·84	1·5769	5·39	1·6845
3·75	1·3218	4·30	1·4586	4·85	1·5790	5·40	1·6864

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
5·41	1·6882	5·96	1·7851	6·51	1·8733	7·06	1·9544
5·42	1·6901	5·97	1·7867	6·52	1·8749	7·07	1·9559
5·43	1·6919	5·98	1·7884	6·53	1·8764	7·08	1·9573
5·44	1·6938	5·99	1·7901	6·54	1·8779	7·09	1·9587
5·45	1·6956	6·00	1·7918	6·55	1·8795	7·10	1·9601
5·46	1·6974	6·01	1·7934	6·56	1·8810	7·11	1·9615
5·47	1·6993	6·02	1·7951	6·57	1·8825	7·12	1·9629
5·48	1·7011	6·03	1·7967	6·58	1·8840	7·13	1·9643
5·49	1·7029	6·04	1·7984	6·59	1·8856	7·14	1·9657
5·50	1·7047	6·05	1·8001	6·60	1·8871	7·15	1·9671
5·51	1·7066	6·06	1·8017	6·61	1·8886	7·16	1·9685
5·52	1·7084	6·07	1·8034	6·62	1·8901	7·17	1·9699
5·53	1·7102	6·08	1·8050	6·63	1·8916	7·18	1·9713
5·54	1·7120	6·09	1·8066	6·64	1·8931	7·19	1·9727
5·55	1·7138	6·10	1·8083	6·65	1·8946	7·20	1·9741
5·56	1·7156	6·11	1·8099	6·66	1·8961	7·21	1·9755
5·57	1·7174	6·12	1·8116	6·67	1·8976	7·22	1·9769
5·58	1·7192	6·13	1·8132	6·68	1·8991	7·23	1·9782
5·59	1·7210	6·14	1·8148	6·69	1·9006	7·24	1·9796
5·60	1·7228	6·15	1·8165	6·70	1·9021	7·25	1·9810
5·61	1·7246	6·16	1·8181	6·71	1·9036	7·26	1·9824
5·62	1·7263	6·17	1·8197	6·72	1·9051	7·27	1·9838
5·63	1·7281	6·18	1·8213	6·73	1·9066	7·28	1·9851
5·64	1·7299	6·19	1·8229	6·74	1·9081	7·29	1·9865
5·65	1·7317	6·20	1·8245	6·75	1·9095	7·30	1·9879
5·66	1·7334	6·21	1·8262	6·76	1·9110	7·31	1·9892
5·67	1·7352	6·22	1·8278	6·77	1·9125	7·32	1·9906
5·68	1·7370	6·23	1·8294	6·78	1·9140	7·33	1·9920
5·69	1·7387	6·24	1·8310	6·79	1·9155	7·34	1·9933
5·70	1·7405	6·25	1·8326	6·80	1·9169	7·35	1·9947
5·71	1·7422	6·26	1·8342	6·81	1·9184	7·36	1·9961
5·72	1·7440	6·27	1·8358	6·82	1·9199	7·37	1·9974
5·73	1·7457	6·28	1·8374	6·83	1·9213	7·38	1·9988
5·74	1·7475	6·29	1·8390	6·84	1·9228	7·39	2·0001
5·75	1·7492	6·30	1·8405	6·85	1·9242	7·40	2·0015
5·76	1·7509	6·31	1·8421	6·86	1·9257	7·41	2·0028
5·77	1·7527	6·32	1·8437	6·87	1·9272	7·42	2·0042
5·78	1·7544	6·33	1·8453	6·88	1·9286	7·43	2·0055
5·79	1·7561	6·34	1·8469	6·89	1·9301	7·44	2·0069
5·80	1·7579	6·35	1·8485	6·90	1·9315	7·45	2·0082
5·81	1·7596	6·36	1·8500	6·91	1·9330	7·46	2·0096
5·82	1·7613	6·37	1·8516	6·92	1·9344	7·47	2·0109
5·83	1·7630	6·38	1·8532	6·93	1·9359	7·48	2·0122
5·84	1·7647	6·39	1·8547	6·94	1·9373	7·49	2·0136
5·85	1·7664	6·40	1·8563	6·95	1·9387	7·50	2·0149
5·86	1·7681	6·41	1·8579	6·96	1·9402	7·51	2·0162
5·87	1·7699	6·42	1·8594	6·97	1·9416	7·52	2·0176
5·88	1·7716	6·43	1·8610	6·98	1·9430	7·53	2·0189
5·89	1·7733	6·44	1·8625	6·99	1·9445	7·54	2·0202
5·90	1·7750	6·45	1·8641	7·00	1·9459	7·55	2·0215
5·91	1·7766	6·46	1·8656	7·01	1·9473	7·56	2·0229
5·92	1·7783	6·47	1·8672	7·02	1·9488	7·57	2·0242
5·93	1·7800	6·48	1·8687	7·03	1·9502	7·58	2·0255
5·94	1·7817	6·49	1·8703	7·04	1·9516	7·59	2·0268
5·95	1·7834	6·50	1·8718	7·05	1·9530	7·60	2·0281

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
7·61	2·0295	8·16	2·0992	8·71	2·1645	9·26	2·2257
7·62	2·0308	8·17	2·1005	8·72	2·1656	9·27	2·2268
7·63	2·0321	8·18	2·1017	8·73	2·1668	9·28	2·2279
7·64	2·0334	8·19	2·1029	8·74	2·1679	9·29	2·2289
7·65	2·0347	8·20	2·1041	8·75	2·1691	9·30	2·2300
7·66	2·0360	8·21	2·1054	8·76	2·1702	9·31	2·2311
7·67	2·0373	8·22	2·1066	8·77	2·1713	9·32	2·2322
7·68	2·0386	8·23	2·1078	8·78	2·1725	9·33	2·2332
7·69	2·0399	8·24	2·1090	8·79	2·1736	9·34	2·2343
7·70	2·0412	8·25	2·1102	8·80	2·1748	9·35	2·2354
7·71	2·0425	8·26	2·1114	8·81	2·1759	9·36	2·2364
7·72	2·0438	8·27	2·1126	8·82	2·1770	9·37	2·2375
7·73	2·0451	8·28	2·1138	8·83	2·1782	9·38	2·2386
7·74	2·0464	8·29	2·1150	8·84	2·1793	9·39	2·2396
7·75	2·0477	8·30	2·1163	8·85	2·1804	9·40	2·2407
7·76	2·0490	8·31	2·1175	8·86	2·1815	9·41	2·2418
7·77	2·0503	8·32	2·1187	8·87	2·1827	9·42	2·2428
7·78	2·0516	8·33	2·1199	8·88	2·1838	9·43	2·2439
7·79	2·0528	8·34	2·1211	8·89	2·1849	9·44	2·2450
7·80	2·0541	8·35	2·1223	8·90	2·1861	9·45	2·2460
7·81	2·0554	8·36	2·1235	8·91	2·1872	9·46	2·2471
7·82	2·0567	8·37	2·1247	8·92	2·1883	9·47	2·2481
7·83	2·0580	8·38	2·1258	8·93	2·1894	9·48	2·2492
7·84	2·0592	8·39	2·1270	8·94	2·1905	9·49	2·2502
7·85	2·0605	8·40	2·1282	8·95	2·1917	9·50	2·2513
7·86	2·0618	8·41	2·1294	8·96	2·1928	9·51	2·2523
7·87	2·0631	8·42	2·1306	8·97	2·1939	9·52	2·2534
7·88	2·0643	8·43	2·1318	8·98	2·1950	9·53	2·2544
7·89	2·0656	8·44	2·1330	8·99	2·1961	9·54	2·2555
7·90	2·0669	8·45	2·1342	9·00	2·1972	9·55	2·2565
7·91	2·0681	8·46	2·1353	9·01	2·1983	9·56	2·2576
7·92	2·0694	8·47	2·1365	9·02	2·1994	9·57	2·2586
7·93	2·0707	8·48	2·1377	9·03	2·2006	9·58	2·2597
7·94	2·0719	8·49	2·1389	9·04	2·2017	9·59	2·2607
7·95	2·0732	8·50	2·1401	9·05	2·2028	9·60	2·2618
7·96	2·0744	8·51	2·1412	9·06	2·2039	9·61	2·2628
7·97	2·0757	8·52	2·1424	9·07	2·2050	9·62	2·2638
7·98	2·0769	8·53	2·1436	9·08	2·2061	9·63	2·2649
7·99	2·0782	8·54	2·1448	9·09	2·2072	9·64	2·2659
8·00	2·0794	8·55	2·1459	9·10	2·2083	9·65	2·2670
8·01	2·0807	8·56	2·1471	9·11	2·2094	9·66	2·2680
8·02	2·0819	8·57	2·1483	9·12	2·2105	9·67	2·2690
8·03	2·0832	8·58	2·1494	9·13	2·2116	9·68	2·2701
8·04	2·0844	8·59	2·1506	9·14	2·2127	9·69	2·2711
8·05	2·0857	8·60	2·1518	9·15	2·2138	9·70	2·2721
8·06	2·0869	8·61	2·1529	9·16	2·2148	9·71	2·2732
8·07	2·0882	8·62	2·1541	9·17	2·2159	9·72	2·2742
8·08	2·0894	8·63	2·1552	9·18	2·2170	9·73	2·2752
8·09	2·0906	8·64	2·1564	9·19	2·2181	9·74	2·2762
8·10	2·0919	8·65	2·1576	9·20	2·2192	9·75	2·2773
8·11	2·0931	8·66	2·1587	9·21	2·2203	9·76	2·2783
8·12	2·0943	8·67	2·1599	9·22	2·2214	9·77	2·2793
8·13	2·0956	8·68	2·1610	9·23	2·2225	9·78	2·2803
8·14	2·0968	8·69	2·1622	9·24	2·2235	9·79	2·2814
8·15	2·0980	8·70	2·1633	9·25	2·2246	9·80	2·2824

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
9·81	2·2834	**15·00**	2·7081	**49·00**	3·8918	**88·00**	4·4770
9·82	2·2844	**15·50**	2·7408	**50·00**	3·9120	**89·00**	4·4887
9·83	2·2854	**16·00**	2·7726	**51·00**	3·9319	**90·00**	4·4997
9·84	2·2865	**16·50**	2·8034	**52·00**	3·9513	**91·00**	4·5108
9·85	2·2875	**17·00**	2·8332	**53·00**	3·9704	**92·00**	4·5218
9·86	2·2885	**17·50**	2·8621	**54·00**	3·9890	**93·00**	4·5327
9·87	2·2895	**18·00**	2·8904	**55·00**	4·0084	**94·00**	4·5433
9·88	2·2905	**18·50**	2·9173	**56·00**	4·0254	**95·00**	4·5539
9·89	2·2915	**19·00**	2·9444	**57·00**	4·0431	**96·00**	4·5644
9·90	2·2925	**19·50**	2·9703	**58·00**	4·0604	**97·00**	4·5748
9·91	2·2935	**20·00**	2·9957	**59·00**	4·0683	**98·00**	4·5849
9·92	2·2946	**21·00**	3·0445	**60·00**	4·0945	**99·00**	4·5951
9·93	2·2956	**22·00**	3·0911	**61·00**	4·1108	**100·00**	4·6052
9·94	2·2966	**23·00**	3·1355	**62·00**	4·1272	**101·00**	4·6151
9·95	2·2976	**24·00**	3·1781	**63·00**	4·1431	**102·00**	4·6250
9·96	2·2986	**25·00**	3·2189	**64·00**	4·1590	**103·00**	4·6347
9·97	2·2996	**26·00**	3·2581	**65·00**	4·1744	**104·00**	4·6443
9·98	2·3006	**27·00**	3·2958	**66·00**	4·1896	**105·00**	4·6540
9·99	2·3016	**28·00**	3·3322	**67·00**	4·2048	**106·00**	4·6635
10·00	2·3026	**29·00**	3·3673	**68·00**	4·2098	**107·00**	4·6729
10·25	2·3279	**30·00**	3·4012	**69·00**	4·2343	**108·00**	4·6822
10·50	2·3513	**31·00**	3·4340	**70·00**	4·2388	**109·00**	4·6913
10·75	2·3749	**32·00**	3·4657	**71·00**	4·2628	**110·00**	4·7005
11·00	2·3979	**33·00**	3·4965	**72·00**	4·2766	**111·00**	4·7095
11·25	2·4201	**34·00**	3·5263	**73·00**	4·2904	**112·00**	4·7185
11·50	2·4430	**35·00**	3·5553	**74·00**	4·3040	**113·00**	4·7275
11·75	2·4636	**36·00**	3·5835	**75·00**	4·3176	**114·00**	4·7362
12·00	2·4849	**37·00**	3·6109	**76·00**	4·3307	**115·00**	4·7450
12·25	2·5052	**38·00**	3·6376	**77·00**	4·3439	**116·00**	4·7537
12·50	2·5262	**39·00**	3·6636	**78·00**	4·3567	**117·00**	4·7622
12·75	2·5455	**40·00**	3·6889	**79·00**	4·3694	**118·00**	4·7708
13·00	2·5649	**41·00**	3·7136	**80·00**	4·3821	**119·00**	4·7790
13·25	2·5840	**42·00**	3·7377	**81·00**	4·3945	**120·00**	4·7876
13·50	2·6027	**43·00**	3·7612	**82·00**	4·4067	**121·00**	4·7959
13·75	2·6211	**44·00**	3·7842	**83·00**	4·4189	**122·00**	4·8041
14·00	2·6391	**45·00**	3·8067	**84·00**	4·4309	**123·00**	4·8122
14·25	2·6567	**46·00**	3·8286	**85·00**	4·4426	**124·00**	4·8203
14·50	2·6740	**47·00**	3·8501	**86·00**	4·4544	**125·00**	4·8283
14·75	2·6913	**48·00**	3·8712	**87·00**	4·4659		

EXPONENTIAL AND HYPERBOLIC FUNCTIONS.

x	e^x	e^{-x}	cosh x	sinh x	tanh x
·1	1·1052	·9048	1·0050	·1002	·0997
·2	1·2214	·8187	1·0201	·2013	·1974
·3	1·3499	·7408	1·0453	·3045	·2913
·4	1·4918	·6703	1·0811	·4108	·3799
·5	1·6487	·6065	1·1276	·5211	·4621
·6	1·8221	·5488	1·1855	·6367	·5370
·7	2·0138	·4966	1·2552	·7586	·6044
·8	2·2255	·4493	1·3374	·8881	·6640
·9	2·4596	·4066	1·4331	1·0265	·7163
1·0	2·7183	·3679	1·5431	1·1752	·7616
1·1	3·0042	·3329	1·6685	1·3357	·8005
1·2	3·3201	·3012	1·8107	1·5095	·8337
1·3	3·6693	·2725	1·9709	1·6984	·8617
1·4	4·0552	·2466	2·1509	1·9043	·8854
1·5	4·4817	·2231	2·3524	2·1293	·9051
1·6	4·9530	·2019	2·5775	2·3756	·9217
1·7	5·4739	·1827	2·8283	2·6456	·9354
1·8	6·0496	·1653	3·1075	2·9422	·9468
1·9	6·6589	·1496	3·4177	3·2682	·9563
2·0	7·3891	·1353	3·7622	3·6269	·9640
2·1	8·1662	·1225	4·1443	4·0219	·9704
2·2	9·0251	·1108	4·5679	4·4571	·9758
2·3	9·9742	·1003	5·0372	4·9370	·9801
2·4	11·0232	·0907	5·5570	5·4662	·9837
2·5	12·1825	·0821	6·1323	6·0502	·9866
2·6	13·4638	·0743	6·7690	6·6947	·9890
2·7	14·8797	·0672	7·4735	7·4063	·9910
2·8	16·4446	·0608	8·2527	8·1919	·9926
2·9	18·1741	·0550	9·1146	9·0596	·9940
3·0	20·0855	·0498	10·068	10·018	·9951
3·1	22·1980	·0450	11·122	11·076	·9959
3·2	24·5325	·0408	12·287	12·246	·9967
3·3	27·1126	·0369	13·575	13·538	·9973
3·4	29·9641	·0334	14·999	14·965	·9978
3·5	33·1155	·0302	16·573	16·543	·9982
3·6	36·5982	·0273	18·313	18·285	·9985
3·7	40·4473	·0247	20·236	20·211	·9988
3·8	44·7012	·0224	22·362	22·339	·9990
3·9	49·4024	·0202	24·711	24·691	·9992
4·0	54·5982	·0183	27·308	27·290	·9993
4·1	60·3403	·0166	30·178	30·162	·9995
4·2	66·6863	·0150	33·351	33·336	·9996
4·3	73·6998	·0136	36·857	36·843	·9996
4·4	81·4509	·0123	40·732	40·719	·9997
4·5	90·0171	·0111	45·014	45·003	·9997
4·6	99·4843	·0101	49·747	49·737	·9998
4·7	109·9472	·0091	54·978	54·969	·9998
4·8	121·5104	·0082	60·759	60·751	·9999
4·9	134·2898	·0074	67·149	67·141	·9999
5·0	148·4132	·0067	74·210	74·203	·9999

MEASUREMENT CONVERSION FACTORS.

Angle.

1 radian	= 57·296 degrees.	1 degree	= ·0175 radian.

Length.

1 inch	= 2·54 c.m.	1 c.m.	= ·39370113 inch.
1 foot	= 30·4799 c.m.	1 metre	= 39·370113 inches.
1 yard	= ·914399 metre.		= 3·280843 feet.
1 mile	= 5280 feet.		= 1·0936143 yards.
1 mile	= 1·6093 kilometres.	1 kilometre	= ·62137 mile.
1 link	= ·66 foot.	1 micro m.m.	= ·001 mm.
1 chain	= 66 ft. = 100 links.	1 mil.	= ·001 inch.
1 chain	= 20·1168 metres.		= ·0254 m.m.
1 knot	= 6080 ft. per hour.	Seconds pendulum at Greenwich	= 39·139 ins.
			= 99·413 c.m.

Area.

1 sq. inch	= 6·4516 sq. c.m.	1 sq. c.m.	= ·15500 sq. inch.
1 sq. foot	= 929·03 sq. c.m.	1 sq. metre	= 10·7639 sq. feet.
1 sq. yard	= ·836126 sq. metre.		= 1·196 sq. yards.
1 acre	= ·40468 hectare.	1 are	= 100 sq. metres.
	= 43560 sq. feet.	1 hectare	= 2·4711 acres.
	= 4,840 sq. yards.	1 sq. mile	= 259 hectares.
	= 100,000 sq. links.		= 640 acres.
	= 40·468 ares.		

Volume.

1 cu. inch	= 16·387 c.c.	1 c.c.	= ·061 cu. inch.
1 cu. foot	= ·028317 cu. m.	1 litre	= 1 cu. decimetre.
	= 28·317 litres.		= 61·024 cu. inches.
1 cu. yard	= ·764553 cu. m.		= 1·7598 pints.
	= 764·553 litres.		= ·219985 gal.
1 gallon	= 1·2 U.S.A. gal.	1 cu. m.	= 35·3148 cu. feet.
	= 4·545963 litres.		= 1·307954 cu. yds.
	= ·1605 cu. foot.	1 U.S.A. gal.	= ·83254 Imp. gal.
	= 277·27 cu. inches.		= 231 cu. inches.
1 pint	= ·5682 litre.		= 3·785 litres.
	= 34·67 cu. inches.	8 fl. drachms	= 1 fl. ounce.
1 fl. drachm	= 60 minims.	1 fl. ounce	= 28·41 c.c.
	= 3·55 c.c.	1 pint	= 20 fluid ounces.

Mass.

1 grain	= ·0648 gramme.	1 milligram	= ·001 gramme.
1 pennyw't.	= 1·5552 gramme.		= ·015432 grain.
1 dram	= 1·772 gramme.	1 gramme	= ·0022046 lb.
1 oz. (av.)	= 437·5 grains.		= 15·432 grains.
	= 28·350 grammes.	1 kilo.	= 2·2046 lbs.
1 oz. (troy)	= 480 grains.	1 quintal	= 100 kilos.
	= 31·1035 grammes.		= 1·968 cwt.
1 oz. (apoth.)	= 31·1035 grammes.	1 tonne	= 1,000 kilos.
1 pound (av.)	= 16 ounces.		= ·9842 (Br.) ton.
	= 7,000 grains.	1 ton (U.S.A.)	= 2,000 lbs.
	= 453·5924 grammes		= ·908 tonnes.
1 cwt.	= 50·8 kilos.		= ·89286 (Br.) ton.
1 ton (British)	= 1·016 tonnes.		
	= 1,016 kilos.		
	= 1·12 U.S.A. tons.		

Density.

1 c.c.	of water at 4 deg. Cen. weighs	1 gramme.
1 cubic foot	,, ,, ,,	62·43 lbs.
1 cubic inch	,, ,, ,,	252·89 grains.
1 litre	,, ,, ,,	1 kilogramme.
1 cubic foot air at 0 deg. Cen. and 760 m.m.		= ·08073 lbs.
1 c.c.	,, ,, ,,	= ·001293 gramme.
1 litre	,, ,, ,,	= 1·293 gramme.
1 cc. mercury at 0 deg. Cen.		= 13·5956 gms.
1 gm. per c.c.		= 62·43 lbs. per cubic ft.
Density of Saturated Air		= A – ·608W
,, Dry ,,		= A
,, Water vapour		= W.

Pressure and Force.

1 in. Hg. at o deg. C	= ·4912 lbs. per sq. inch.
	= ·4321 ft. of water.
	= ·034534 kilos. per sq. c.m.
1 m.m. of Hg.	= ·01903 lbs. per sq. inch.
	= ·017011 ft. water.
	= ·204132 in. water.
1 lb.	= ·4536 kilo.
	= 445,000 dynes.
1 poundal	= 13,825 dynes.
Standard atmosphere	= 760 dynes of Hg.
	= 1,013,600 dynes.
	= 29·921 ins. Hg.
	= 14·7 lbs. per sq. in.
	= 33·93 ft. water.
	= 1·0333 kilos. per sq. c.m.
1 ft. water	= 62·43 lbs. per sq.ft.
	= ·43 lb. per sq. in.
	= ·0304 kilo. per sq. cm.
1 kilo.	= 981,000 dynes.
1 lb. per sq. in.	= 2·0358 ins. of Hg.
	= 51·713 m.m. of Hg.
	= 2·3142 ft. of water.
	= 27·71 in. of water.
	= ·070307 kilos. per sq. c.m.
	= 68,971 dynes per sq. c.m.
1 lb. per sq. in.	= 3·3266 dynes per sq. c.m.
1 lb. per sq. ft.	= 4·8826 kilos. per sq. m.
1 kilo. per sq. c.m.	= 14·223 lbs. per sq. inch.
	= 32·84 ft. water.
1 kilo per sq. m.m.	= ·6349 tons per sq. inch.
1 ton per sq. inch	= 1·575 kilos per sq. m.m.
1 gm. per sq. cm.	= ·014223 lbs. per sq inch.
g. (Greenw'h)	= 32·19 ft. per sec. per sec.
	= 981·17 c.m. per sec per sec.
g (lat. 45 deg)	= 980·61 c.m. per sec per sec.

*g = 980·606 – 2·503 cos 2 L – ·000003 H.

* H = height above sea level in centimetres.
L = latitude.

Energy and Power.

1 ft. lb.	=	·13825 metre-kilos.
	=	·0007142lb. deg. C.
	=	13,562.000 ergs.
	=	13,825 c.m. gms.
	=	1·3558 joules.
	=	·3241 gm. calories.
1 gramme calorie	=	·003968 B.Th.U.
	=	4·1834 joules.
1 kilo-calorie	=	3·968 B.Th.U.
	=	3088 ft. lbs.
	=	426·9 metre-kilos.
	=	4·484 joules.
	=	4184 × 10 ergs.
1 horse power	=	746 watts.
	=	33,000 ft. lbs. per min.
1 force-de-cheval	=	736 watts.
1 metre-kilo	=	7·2178 ft. lbs.
1 B.Th.U.	=	778 ft. lbs.
1 B.Th.U.	=	1,058 joules.
1 lb. deg. C.	=	1,400 ft. lbss.
1 metre-kilo.	=	98,100,000 ergs.
1 joule	=	10,000,000 ergs.
1 watt-hour	=	2655·2 ft. lbs.
Watts	=	volts × amperes.
	=	joules per second.
1 kilowatt	=	1·341 H.P.
1 Board of Trade Unit	=	1,000 watt-hours.

DENSITY AND RELATIVE VOLUME OF WATER.

Volume of 1 lb. water at 32 deg. Fah. = ·016021 cubic feet = δ.

Temperature in degrees. Fah. $t°$.	Weight of 1 cu. ft. δ lbs.	Relative Volume at t degrees F.	Temperature in degrees. Fah. $t°$.	Weight of 1 cu. ft. δ lbs.	Relative Volume at t degrees F.
32	62·418	1·	145	61·291	1·0184
35	62·422	·9999	150	61·201	1·0199
39·1	62·425	·9999	155	61·096	1·0216
40	62·425	·9999	160	60·991	1·0234
45	62·422	·9999	165	60·843	1·0259
46	62·418	1·	170	60·783	1·0269
50	62·409	1·0001	175	60·665	1·0291
55	62·394	1·0004	180	60·548	1·0310
60	62·372	1·0007	185	60·430	1·0330
65	62·344	1·0012	190	60·314	1·0350
70	62·313	1·0016	195	60·198	1·0370
75	62·275	1·0024	200	60·081	1·0389
80	62·232	1·0030	205	59·930	1·0414
85	62·182	1·0038	210	59·820	1·0434
90	62·133	1·0046	212	59·640	1·0441
95	62·075	1·0055	220	59·577	1·0476
100	62·022	1·0064	230	59·308	1·0524
105	61·960	1·0074	240	59·032	1·0573
110	61·868	1·0089	250	58·750	1·0624
115	61·807	1·0099	260	58·460	1·0678
120	61·715	1·0114	270	58·170	1·0733
125	61·654	1·0124	280	57·880	1·0791
130	61·563	1·0139	290	57·580	1·0900
135	61·472	1·0154	300	57·260	1·0912
140	61·381	1·0169	400	53·630	1·1640

The density of water δ lbs. per cubic foot is well represented by the equation—

$$\delta = 62{\cdot}425 - (\cdot00013 - \cdot000000187\ t)[t - 40]^2$$

when t is the temperature on the Fahrenheit scale.

The volume v at t deg. Centigrade is given by

$$v = v_0\ (1 - \cdot0000615\ t + \cdot00000772\ t^2 - \cdot0000000373\ t^3)$$

where v_0 is the volume at freezing point.

TEMPERATURE CONVERSION TABLE.

Fahrenheit to Centigrade.

$$F = \frac{9}{5}C + 32 \;\&\; C = \frac{5}{9}\left(F - 32\right)$$

where F = temperature on Fah. scale and
C = temperature on Cent. scale.

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
14	—10	62	16·7	110	43·3	158	70	212	100
15	— 9·4	63	17·2	111	43·9	159	70·6	214	101·1
16	— 8·9	64	17·8	112	44·4	160	71·1	216	102·2
17	— 8·3	65	18·3	113	45	161	71·7	218	103·3
18	— 7·8	66	18·9	114	45·6	162	72·2	220	104·4
19	— 7·2	67	19·4	115	46·1	163	72·8	222	105·6
20	— 6·7	68	20	116	46·7	164	73·3	224	106·7
21	— 6·1	69	20·6	117	47·2	165	73·9	226	107·8
22	— 5·6	70	21·1	118	47·8	166	74·4	228	108·9
23	— 5	71	21·7	119	48·3	167	75	230	110
24	— 4·4	72	22·2	120	48·9	168	75·6	232	111·1
25	— 3·9	73	22·8	121	49·4	169	76·1	234	112·2
26	— 3·3	74	23·3	122	50	170	76·7	236	113·3
27	— 2·8	75	23·9	123	50·6	171	77·2	238	114·4
28	— 2·2	76	24·4	124	51·1	172	77·8	240	115·6
29	— 1·7	77	25	125	51·7	173	78·3	242	116·7
30	— 1·1	78	25·6	126	52·2	174	78·9	244	117·8
31	— 0·6	79	26·1	127	52·8	175	79·4	246	118·9
32	0	80	26·7	128	53·3	176	80	248	120
33	0·6	81	27·2	129	53·9	177	80·6	250	121·1
34	1·1	82	27·8	130	54·4	178	81·1	252	122·2
35	1·7	83	28·3	131	55	179	81·7	254	123·3
36	2·2	84	28·9	132	55·6	180	82·2	256	124·4
37	2·8	85	29·4	133	56·1	181	82·8	258	125·6
38	3·3	86	30	134	56·7	182	83·3	260	126·7
39	3·9	87	30·6	135	57·2	183	83·9	262	127·8
40	4·4	88	31·1	136	57·8	184	84·4	264	128·9
41	5	89	31·7	137	58·3	185	85	266	130
42	5·6	90	32·2	138	58·9	186	85·6	268	131·1
43	6·1	91	32·8	139	59·4	187	86·1	270	132·2
44	6·7	92	33 3	140	60	188	86·7	272	133·3
45	7·2	93	33·9	141	60·6	189	87·2	274	134·4
46	7·8	94	34·4	142	61·1	190	87·8	276	135·6
47	8·3	95	35	143	61·7	191	88·3	278	136·7
48	8·9	96	35·6	144	62·2	192	88·9	280	137·8
49	9·4	97	36·1	145	62·8	193	89·4	282	138·9
50	10	98	36·7	146	63·3	194	90	284	140
51	10·6	99	37·2	147	63·9	195	90·6	286	141·1
52	11·1	100	37·8	148	64·4	196	91·1	288	142·2
53	11·7	101	38·3	149	65	197	91·7	290	143·3
54	12·2	102	38·9	150	65·6	198	92·2	292	144·4
55	12·8	103	39·4	151	66·1	199	92·8	294	145·6
56	13·3	104	40	152	66·7	200	93·3	296	146·7
57	13·9	105	40·6	153	67·2	202	94·4	298	147·8
58	14·4	106	41·1	154	67·8	204	95·6	300	148·9
59	15	107	41·7	155	68·3	206	96·7		
60	15·6	108	42·2	156	68·9	208	97·8		
61	16·1	109	42·8	157	69·4	210	98·9		

TEMPERATURE CONVERSION TABLE.

Centigrade to Fahrenheit.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
—10	14	23	73·4	56	132·8	89	192·2	122	251·6
— 9	15·8	24	75·2	57	134·6	90	194	123	253·4
— 8	17·6	25	77	58	136·4	91	195·8	124	255·2
— 7	19·4	26	78·8	59	138·2	92	197·6	125	257
— 6	21·2	27	80·6	60	140	93	199·4	126	258·8
— 5	23	28	82·4	61	141·8	94	201·2	127	260·6
— 4	24·8	29	84·2	62	143·6	95	203	128	262·4
— 3	26·6	30	86	63	145·4	96	204·8	129	264·2
— 2	28·4	31	87·8	64	147·2	97	206·6	130	266
— 1	30·2	32	89·6	65	149	98	208·4	131	267·8
0	32	33	91·4	66	150·8	99	210·2	132	269·6
1	33·8	34	93·2	67	152·6	100	212	133	271·4
2	35·6	35	95	68	154·4	101	213·8	134	273·2
3	37·4	36	96·8	69	156·2	102	215·6	135	275
4	39·2	37	98·6	70	158	103	217·4	136	276·8
5	41	38	100·4	71	159·8	104	219·2	137	278 6
6	42·8	39	102·2	72	161·6	105	221	138	280·4
7	44·6	40	104	73	163·4	106	222·8	139	282·2
8	46·4	41	105·8	74	165·2	107	224·6	140	284
9	48·2	42	107·6	75	167	108	226·4	141	285·8
10	50	43	109·4	76	168·8	109	228·2	142	287·6
11	51·8	44	111·2	77	170·6	110	230	143	289·4
12	53·6	45	113	78	172·4	111	231·8	144	291·2
13	55·4	46	114·8	79	174·2	112	233·6	145	293
14	57·2	47	116·6	80	176	113	235·4	146	294·8
15	59	48	118·4	81	177·8	114	237·2	147	296·6
16	60·8	49	120·2	82	179·6	115	239	148	298·4
17	62·6	50	122	83	181·4	116	240·8	149	300·2
18	64·4	51	123·8	84	183·2	117	242·6	150	302
19	66·2	52	125·6	85	185	118	244·4		
20	68	53	127·4	86	186·8	119	246·2		
21	69·8	54	129·2	87	188·6	120	248		
22	71·6	55	131	88	190·4	121	249·8		

DENSITY, SPECIFIC HEAT, COEFFICIENT OF EXPANSION, AND MELTING POINT OF METALS AND OTHER SUBSTANCES.

Substance.	Specific Gravity.	Density, lbs. per cu. ft.	Specific Heat.	Coefficient of Expansion of Volume per deg. Fah.	Melting Point in	
					Deg. Cen.	Deg. Fah.
Water at 32 deg. F	1	62·42	1	..	..	..
Aluminium (Cast)...	2·6	161·7	·212	·000034	657	1214
Antimony	6·71	417	·051	..	630	1166
Bismuth	9·82	613	·031	·000023	269	520
Brass	8·1	503	·094	·000031	900	1650
Copper	8·79	545	·092	·000031	1084	1982
Coal (Anthracite)..	1·43	88·7	·241	..	..	..
Coke	1	62·4	·203	..	..	..
Glass	2·89	180·7	·198	·000013	1100	2007
Gold	19·26	1200	·032	·000025	1064	1946
Ice at 32 deg. Fah.	·92	57·5	·504	..	..	32
Iron (Cast)	7·5	465	·130	·000018	1075	1960
Iron (Wrought) ..	7·74	582	·114	·000022	1520	2768
Lead	11·35	708	·031	·000048	327	621
Limestone.....	3·16	197	·217	..	..	..
Mercury	13·598	848·7	·033	·000101	−38·7	−37·7
Masonry & Cement	2·24	140	·2	·000023	..	..
Nickel	8·9	547	·109	·000020	1452	2646
Oak	·86	54	·57	..	..	..
Oil (Petroleum) ...	·88	55	·659	..	..	..
Platinum	21·5	1342	·032	·000015	1755	3191
Pine (White) ...	·55	34·6	·65	..	..	..
Sulphur	2·07	127	·203	..	115	239
Silver.....	10·474	653	·056	·000033	960	1761
Steel	7·83	486	·116	·000020	1370	2790
Tin.....	7·29	452	·056	·000035	232	449
Zinc	7·19	445	·095	·000049	419	787

The specific heat in the above table is referred to water as unity. The figures in the column are the number of British thermal units required to raise one pound of the substance through 1 deg. Fah.

Linear Coefficient of Expansion —This is one third of that given in the above table. It should be noted that the coefficients given are the *absolute coefficients.* The expansion generally observed is the absolute expansion *minus* the expansion of the containing vessel.

CONSTANTS RELATING TO COMBUSTION.

	Atomic Weight H = 1.	Molecular Weight H_2 = 2.	Specific Gravity at 32 deg. Fah. and 14·7 lbs. per sq. in. Water = 1.	Density in Pounds per Cubic Foot, at 32 deg. Fah. and 14·7 lbs. per sq. in.	Specific Heat at Constant Pressure Cp.	Specific Heat at Constant Volume Cv.	Co-efficient of Expansion of Volume at Constant Pressure per degree C.	Co-efficient of Expansion of Volume at Constant Pressure per degree F.	Higher Calorific Value. B.Th.U. given out during Combustion with Oxygen, and Products Cooled to 32 deg. Fah.	Lower Calorific Value, Products Cooled to 212 deg. Fah.
Air	..	..	·00130	·0807	·2374	·1690	·003665	·002036	..	..
Carbon	11·97	..	2·33*	..	·2411	..	..	..	14500	14500
Carbonic Acid Gas	†	CO_2 43·89	·00198	·1238	·2170	·1710	·003688	·002049	..	..
Carbonic Oxide	†	CO 27·93	·00126	·0773	·2450	·1730	·003667	·002037	4330	4330
Coal Gas (rough average)	..	..	·00054	·0335	..	..	..	..	17800	..
Hydrogen	1	H_2 2	·00009	·00559	3·4090	2·4060	·003667	·002037	62030	51730
Nitrogen	14·01	N_2 28·02	·00126	·0786	·2438‡	·1730‡	·003668	·002038	..	..
Marsh Gas	†	CH_4 15·97	·00072	·1455	·5930	·4670	..	..	23550	20970
Olefiant Gas (Ethylene)	†	C_2H_4 27·94	·00126	·0795	·404	·332	..	..	21420	10950
Oxygen	15·96	O_2 31·92	·00144	·0895	·2175	·155	..	..	..	..
Steam at 212 deg. Fah.	†	H_2O 17·96	·0008	·0502	..	·365	..	..	..	..
Sulphur	31·98	S_2 63·96	2·07	127·	·2026	..	..	..	4000	..
Sulphur Dioxide	†	SO_2 63·9	·00288	·1792	..	..	·003845	·002136	..	..
Refined Petroleum	..	..	·8	49·9	..	..	..	..	22000	..
Crude Petroleum	..	..	·9	56·2	..	..	..	..	20000	..
Alcohol	..	C_2H_6O	·806	50·3	..	..	·001	..	..	..
Petrol (Shell)	..	..	·72	44·9	..	..	·00121	..	..	18700

* Graphite. † The equivalent atomic weights of the above gases will be half the molecular weights. The nearest whole numbers are generally used for the molecular weights in flue gas analysis.

Average specific heat of ash = ·2. Charcoal = ·2 approximate.

Average specific heat of gas engine exhaust gases when coal gas is used = ·258 at constant pressure, and ·189 at constant volume.

Average specific heat of chimney gases ·24 to ·25.

1 lb. carbon burning to CO gives out 4400 B.Th.U.

‡ The specific heat of Nitrogen = ·2246 + ·000038T at constant pressure, and ·1541 + ·000038T at constant volume; when T = absolute temperature Centigrade.

THE STEAM TABLE.

During recent years a considerable amount of research has shown that the results of Regnault's classic experiments were not to be relied upon. On this account a new table has been constructed, and the work of a number of eminent experimenters has been used as the foundation upon which it has been built. These new values of the steam properties are given in two tables, one in Fahrenheit units of temperature and the other in Centigrade units. To economise space, the headings of all of the columns are represented by the usual symbols, except on the first page, where they are given in full for the purpose of reference.

The process of constructing the table consisted of obtaining a fairly large number of values of any given quantity corresponding with the same number of pressures and plotting them to a large scale on imperial sheets of squared paper, using pressure as base. Curves were then carefully drawn through the plotted points, and the values read off the curves at intervals of single pounds or less. The differences were then adjusted to make them regular, and this acted as a check upon the accuracy of the readings from the curve.

Temperature.—The temperature of saturated steam corresponding to any pressure is given in the second column of both tables. The following equation * has been used to calculate a large number of corresponding values for the purpose of plotting the pressure temperature curve.

$$\log_{10} p = 10{\cdot}515354 - 4873{\cdot}71T^{-1} - {\cdot}00405096T + {\cdot}000001392964T^2$$

where p = absolute pressure in lbs. per square inch ;
T = absolute temperature Fah. ;
= $459{\cdot}6 + t$;
t = temperature on the ordinary scale.

This equation agrees with the experimental values of Holborn and Baumann from 400 deg. Fah. up to the critical temperature 706 deg. Fah., of Holborn and Henning from 120 deg. Fah. to 400 deg. Fah., and of other investigators below 120 deg. Fah. The maximum difference between the values obtained from the equation and the experimental values nowhere reaches one-fifth per cent ; and except over the range from 50 deg. Fah. to 200 deg. Fah., the difference does not reach one-tenth per cent. The temperatures obtained by Regnault do not differ appreciably from those in the table.

Sensible Heat.—The most recent work of Prof. Callendar* is very accurately represented by the equation—

* "The Pressure-Temperature Relations of Saturated Steam," by Prof. Marks, Proc. Am. Soc. Mech. Engineers, 1911.

† Proc. Royal Society,

$$S = \cdot 9854\,(t - 32) + 2\cdot 089 \log_{10}\left(\frac{t+4}{36}\right) + \cdot 233\left(\frac{t-32}{100}\right)^2 + \cdot 118\left(\frac{t-32}{100}\right)^3$$

t representing temperature on the ordinary Fahrenheit scale, and S the sensible heat in B.Th.U. per lb.

Prof. Callendar used the coefficient ·107 in the last term, and his range of experiment extended from freezing to the ordinary boiling point. The coefficient ·118 does not affect the values of the sensible heat over this range as far as the first decimal place is concerned; but it increases the range of its application so as to include temperatures up to 400 deg. Fah., with a probable error of not more than two-fifths of a unit of heat at the latter temperature. It should be noted that the sensible heat is here understood to include the heat equivalent of the work done in forcing 1 lb. water into the boiler at the pressure corresponding to the temperature. This quantity of heat is negligible up to 200 deg. Fah., but amounts to about ·8 of a unit at 400 deg. Fah. Callendar's experiments cited above confirm the results obtained by Barnes ten years previously. Above the ordinary boiling point the result of experiments by Dieterici and Regnault only are available; but these are not considered so reliable as those of Callendar and Barnes up to 210 deg. Fah.

In centigrade and lb. units the above equation becomes

$$S = \cdot 9854t + 1\cdot 1605 \log_{10}\left(\frac{t+20}{20}\right) + \cdot 42\left(\frac{t}{100}\right)^2 + \cdot 03\left(\frac{t}{100}\right)^3$$

Latent Heat.—This quantity has been obtained by subtracting the sensible heat from the total heat. It has been determined experimentally by Henning. Above 10 lbs. per square inch absolute the following empirical equation gives values of the latent heat with great accuracy, but below 10 lbs. per square inch the equation does not hold satisfactorily.

$$L = 121\cdot 68\,(706 - t)^{\cdot 33483}$$

where t = temperature on the Fahrenheit scale and 706 is the critical temperature.

The internal latent heat is $\left(L - \frac{Pu}{J}\right)$ and can be obtained by subtracting a number in the sixth column from that in the fourth column.

Total Heat.—This is the most important property of steam to the engineer. No one has extended his researches over a wide range of temperatures except Regnault, but his results have been shown to be unreliable by a number of experimenters, notably Henning, Griffiths, Jolly, Smith, Callendar, Knoblauch, and Jakob. By combining the results obtained by different experimenters*

* Proc. Am. Soc. Mech. Engineers, 1908.

Dr. Davies has obtained values for the total heat which he considers are not likely to be in error to a greater extent than one-tenth per cent, or just about one unit of heat. Prof. Callendar has deduced a rational equation of the form given below for the total heat of steam ; but the constants have been deduced by the author from the results of Dr. Davies already referred to.

$$*H = 1073{\cdot}4 + {\cdot}4586\ (t - 32) - p\left[1{\cdot}0965\left(\frac{491{\cdot}6}{T}\right)^{\frac{10}{3}} - {\cdot}003\right]$$

where H = the total heat of steam in B.Th.U. per lb.,
t = temperature of the steam on the ordinary Fahrenheit scale,
T = absolute temperature of the steam on the Fahrenheit scale,
= $t + 459{\cdot}6$,
p = absolute pressure of steam in lbs. per square inch.

The closeness of the values derived from this equation to those obtained by Dr. Davies is remarkable, the maximum difference over any part of the range being only one in three thousand, or about one-third of a heat unit. This equation has been used in determining the values of the total heat in the fifth column of the table.

In lbs. and Centigrade units the above equation becomes

$$*H = 596{\cdot}3 + {\cdot}4586\,t - p\left[{\cdot}6092\left(\frac{273}{T}\right)^{\frac{10}{3}} - {\cdot}00167\right]$$

The following equation, due to Dr. Davies, holds very well from 210 deg. Fah. to 400 deg. Fah.

$$H = 1150{\cdot}3 + {\cdot}3745\ (t - 212) - {\cdot}00055\ (t - 212)^2$$

Density and Specific Volume.—The latter has been obtained from Clapeyron's equation—

$$\text{Specific vol. } v = 144\ \frac{J\,L}{T} \cdot \frac{dp}{dT} + \sigma = \frac{1}{\delta}$$

where v = volume of 1 lb. steam in cubic feet,
J = Joule's equivalent,
= 778 ft. lbs. per lb. water per deg. Fah.,
= 1,400 ft. lbs. per lb. water per deg. Cen.
L = latent heat,
T = absolute temperature of the steam,
= $459{\cdot}6 + t$ Fah.,
= $273 + t$ Cen.,
σ = volume of 1 lb. water in cubic feet,
δ = density of steam in lbs. per cubic feet,

and $\frac{dp}{dT}$ is obtained by differentiating the previous equation (on page 24) connecting pressure and temperature.

*It should be noted that this equation, without modification, gives the total heat of 1 lb. of *superheated* steam as well as the total heat of saturated steam.

The specific volumes corresponding to a number of different pressures were calculated, and the reciprocals (densities) obtained. These were plotted on a pressure base, and intermediate values read off the curve. The reciprocals of the densities were then calculated. This method is very accurate, as the curve of density on a pressure base is nearly straight. The numbers so obtained agree well with the experimental values of Knoblauch, Linde, and Klebe.

The density of saturated steam above 70 lbs. per square inch in absolute is represented by the equation

$$\delta = \cdot 014 + \cdot 00211\, p$$

where p = pressure in lbs. per square inch.

The Heat Equivalent of the External Work done during the formation of saturated steam is given by the expression

$$E = \frac{144\, p\, (v - \sigma)}{J}$$

$$= \frac{P\, u}{J}$$

where P = pressure in lbs. per square foot,

and u = increase of volume in cubic feet during evaporation.

The internal heat of 1 lb. steam is $(H - E)$.

Entropy.—The entropy of water (ϕ_ω) was obtained step by step from the sensible heats by the equation

$$\triangle \phi_\omega = \frac{\triangle S}{T}$$

when the absolute temperature T was replaced by the average temperature $\frac{1}{2}(T_1 + T_2)$ over the interval corresponding to the increment of heat $\triangle S$, the corresponding increment of entropy being $\triangle \phi$, and the rise of temperature being from T_1 to T_2. If to each value of ϕ_ω the quantity $\frac{L}{T}$ be added, the corresponding value of ϕ_s (the total entropy of saturated steam) is obtained, and is given in the last column of the table.

SATURATED STEAM TABLE (Fahrenheit Units.)

Absolute pressure lbs. per sq. inch.	Temperature in Fah. degrees.	Sensible Heat.	Latent Heat.	Total Heat.	External work.	Specific volume. Cu. ft.	Density lbs. per Cu. ft.	Entropy of Water.	Total Entropy of Steam
p	t °F.	S	L	H	$E=\frac{Pu}{J}$	v	δ	ϕ_ω	ϕ_s
0·089	32·0	0	1073·4	1073·4	54·0	3300	·000303	0	2·185
0·1	35·5	3·5	1071·5	1075·0	54·4	2941	·000340	·007	2·172
0·2	53·0	21·0	1062·1	1083·1	56·4	1531	·000653	·042	2·114
0·3	64·8	32·8	1055·3	1088·1	57·8	1042	·000960	·065	2·080
0·4	73·0	41·0	1050·8	1091·8	59·0	793·6	·00126	·081	2·054
0·5	79·5	47·2	1047·6	1094·8	59·7	645·2	·00155	·096	2·037
0·6	85·3	53·3	1043·9	1097·2	60·2	540·5	·00185	·105	2·022
0·7	90·1	58·0	1041·3	1099·3	60·6	467·3	·00214	·112	2·007
0·8	94·5	62·2	1039·0	1101·2	61·0	411·5	·00243	·119	1·996
0·9	98·5	66·2	1036·8	1103·0	61·4	367·7	·00272	·127	1·986
1·0	101·8	69·5	1035·1	1104·6	61·7	333·3	·00300	·133	1·977
1·1	105·0	72·8	1033·2	1106·0	62·0	304·9	·00328	·139	1·968
1·2	108·0	75·6	1031·6	1107·2	62·3	280·9	·00356	·144	1·961
1·3	110·8	78·5	1029·9	1108·4	62·6	260·4	·00384	·148	1·954
1·4	113·4	81·0	1028·5	1109·5	62·8	242·7	·00412	·152	1·948
1·5	115·8	83·5	1027·1	1110·6	63·1	227·3	·00440	·157	1·943
1·6	118·1	85·8	1025·8	1111·6	63·3	213·7	·00468	·161	1·937
1·7	120·3	88·0	1024·5	1112·5	63·6	202·0	·00495	·165	1·932
1·8	122·4	90·1	1022·7	1113·4	63·8	190·8	·00524	·169	1·927
1·9	124·3	92·0	1022·3	1114·3	64·0	181·8	·00550	·172	1·923
2·0	126·1	93·8	1021·4	1115·2	64·2	173·6	·00576	·175	1·918
2·5	134·2	102·0	1016·8	1118·8	65·2	140·8	·00710	·188	1·900
3·0	141·5	109·2	1012·8	1122·0	66·0	119·0	·00840	·201	1·885
3·5	147·5	115·0	1009·5	1124·5	66·7	103·1	·00970	·211	1·873
4·0	152·9	120·6	1006·1	1126·7	67·3	90·90	·01100	·219	1·863
4·5	157·9	125·4	1002·4	1128·8	67·7	81·24	·01231	·227	1·852
5·0	162·3	129·8	1000·8	1130·6	68·1	73·42	·01362	·234	1·844
6	170·0	137·4	996·4	1133·8	68·8	61·91	·01615	·246	1·828
7	176·7	144·0	992·5	1136·5	69·4	53·60	·01866	·257	1·816
8	182·6	150·0	988·9	1138·9	70·0	47·24	·02117	·267	1·805
9	188·0	155·3	985·7	1141·0	70·5	42·32	·02363	·275	1·796
10	193·0	160·3	982·6	1142·9	70·9	38·37	·02606	·283	1·798
11	197·6	165·0	979·8	1144·8	71·3	35·10	·02849	·291	1·780
12	202·1	169·6	976·9	1146·5	71·7	32·26	·03090	·297	1·773
13	206·0	173·3	974·7	1148·0	72·1	30·03	·03330	·303	1·767
14	209·7	177·0	972·4	1149·4	72·5	28·01	·03570	·308	1·762
14·7	212·0	179·3	970·7	1150·0	72·7	26·77	·03735	·312	1·758
15	213·2	180·5	970·2	1150·7	72·9	26·28	·03805	·314	1·756
16	216·4	183·7	968·2	1151·9	73·2	24·75	·0404	·319	1·750
17	219·2	186·7	966·3	1153·0	73·5	23·42	·0427	·324	1·747
18	222·1	189·8	964·2	1154·0	73·8	22·17	·0451	·327	1·743
19	224·6	192·8	962·1	1154·9	74·0	21·10	·0474	·331	1·738
20	227·3	195·7	960·1	1155·8	74·3	20·12	·0497	·335	1·735

Fahrenheit Units.

p	t°F	S	L	H	$E=\frac{Pu}{J}$	v	δ	ϕ_ω	ϕ_s
21	230·0	198·3	958·4	1156·7	74·6	19·23	·0520	·339	1·730
22	232·6	201·0	956·6	1157·6	74·8	18·42	·0543	·343	1·727
23	235·1	203·7	954·8	1158·5	75·0	17·64	·0567	·346	1·723
24	237·4	206·0	953·4	1159·4	75·2	16·92	·0591	·350	1·719
25	239·8	208·3	951·9	1160·2	75·4	16·29	·0614	·353	1·716
26	242·0	210·5	950·5	1161·0	75·6	15·70	·0637	·357	1·712
27	244·1	212·8	948·9	1161·7	75·7	15·15	·0660	·359	1·709
28	246·1	214·9	947·5	1162·4	75·9	14·64	·0683	·362	1·707
29	248·1	217·0	946·1	1163·1	76·1	14·16	·0706	·365	1·703
30	250·1	219·0	944·7	1163·7	76·3	13·74	·0728	·368	1·700
31	252·0	220·9	943·4	1164·3	76·4	13·33	·0750	·371	1·698
32	253·8	222·8	942·2	1165·0	76·6	12·95	·0772	·374	1·695
33	255·6	224·5	941·2	1165·7	76·7	12·59	·0794	·377	1·692
34	257·3	226·3	939·9	1166·2	76·9	12·24	·0817	·379	1·690
35	259·0	228·1	938·6	1166·7	77·0	11·90	·0840	·381	1·687
36	260·7	229·8	937·4	1167·2	77·2	11·59	·0863	·384	1·685
37	262·3	231·3	936·5	1167·8	77·3	11·29	·0886	·386	1·684
38	263·9	233·1	935·2	1168·3	77·4	11·00	·0909	·388	1·681
39	265·5	234·6	934·2	1168·8	77·6	10·74	·0931	·390	1·679
40	267·0	236·2	933·1	1169·3	77·7	10·49	·0953	·393	1·677
41	268·5	237·8	932·0	1169·8	77·8	10·26	·0975	·395	1·675
42	270·0	239·2	931·1	1170·3	77·9	10·03	·0997	·397	1·673
43	271·5	240·7	930·1	1170·8	78·0	9·813	·1019	·399	1·671
44	273·0	242·2	929·0	1171·2	78·1	9·605	·1041	·401	1·669
45	274·4	243·6	928·0	1171·6	78·3	9·407	·1063	·403	1·667
46	275·7	245·1	927·0	1172·1	78·4	9·216	·1085	·405	1·665
47	277·0	246·4	926·1	1172·5	78·5	9·034	·1107	·407	1·664
48	278·3	247·9	925·1	1173·0	78·6	8·857	·1129	·409	1·662
49	279·6	249·3	924·1	1173·4	78·7	8·688	·1151	·410	1·660
50	280·9	250·5	923·3	1173·8	78·7	8·525	·1173	·412	1·659
51	282·2	252·0	922·1	1174·1	78·8	8·368	·1195	·414	1·657
52	283·5	253·2	921·3	1174·5	78·9	8·218	·1217	·416	1·656
53	284·8	254·5	920·3	1174·8	79·0	8·071	·1239	·417	1·654
54	286·0	255·8	919·4	1175·2	79·1	7·930	·1261	·419	1·652
55	287·1	256·9	918·6	1175·5	79·2	7·794	·1283	·421	1·651
56	288·3	258·1	917·7	1175·8	79·3	7·651	·1307	·422	1·650
57	289·4	259·3	916·9	1176·2	79·3	7·528	·1328	·424	1·649
58	290·5	260·3	916·2	1176·5	79·4	7·407	·1350	·425	1·648
59	291·6	261·5	915·3	1176·8	79·5	7·291	·1371	·427	1·646
60	292·8	262·7	914·4	1177·1	79·5	7·179	·1393	·428	1·645
61	293·9	263·9	913·5	1177·4	79·6	7·070	·1415	·430	1·643
62	295·0	264·9	912·8	1177·7	79·7	6·963	·1436	·432	1·642
63	296·0	266·0	912·0	1178·0	79·7	6·858	·1458	·433	1·641
64	297·0	267·2	911·1	1178·3	79·8	6·756	·1480	·434	1·640
65	298·0	268·2	910·4	1178·6	79·9	6·657	·1502	·436	1·638
66	299·0	269·2	909·7	1178·9	79·9	6·561	·1524	·437	1·637
67	300·0	270·3	908·9	1179·2	80·0	6·468	·1546	·439	1·636
68	301·0	271·3	908·2	1179·5	80·0	6·377	·1568	·440	1·635
69	302·0	272·3	907·4	1179·7	80·1	6·289	·1590	·441	1·634
70	302·9	273·3	906·7	1180·0	80·2	6·204	·1612	·442	1·632

Fahrenheit Units.

p	t°F	S	L	H	$E=\frac{Pu}{J}$	v	δ	ϕ_ω	ϕ_s
71	303·8	274·3	906·0	1180·3	80·2	6·122	·1634	·443	1·631
72	304·7	275·1	905·4	1180·5	80·3	6·042	·1655	·445	1·630
73	305·6	276·1	904·7	1180·8	80·4	5·963	·1677	·446	1·629
74	306·5	277·0	904·1	1181·1	80·4	5·886	·1699	·447	1·628
75	307·4	278·0	903·4	1181·4	80·5	5·811	·1721	·448	1·627
76	308·3	278·9	902·7	1181·6	80·6	5·739	·1742	·449	1·626
77	309·2	279·7	902·1	1181·8	80·6	5·668	·1764	·450	1·625
78	310·1	280·6	901·4	1182·0	80·7	5·599	·1786	·452	1·624
79	311·0	281·5	900·8	1182·3	80·7	5·532	·1807	·453	1·623
80	312·1	282·5	900·0	1182·5	80·8	5·467	·1829	·454	1·622
81	312·9	283·3	899·5	1182·8	80·9	5·405	·1850	·455	1·621
82	313·7	284·3	898·7	1183·0	80·9	5·347	·1870	·456	1·620
83	314·5	285·0	898·3	1183·3	81·0	5·288	·1891	·457	1·619
84	315·3	285·9	897·6	1183·5	81·0	5·229	·1912	·458	1·618
85	316·1	286·7	286·7	1183·7	81·1	5·171	·1934	·460	1·617
86	317·0	287·4	896·5	1183·9	81·1	5·115	·1955	·461	1·616
87	317·9	288·3	895·9	1184·2	81·2	5·060	·1976	·462	1·615
88	318·7	289·1	895·3	1184·4	81·2	5·005	·1998	·463	1·613
89	319·5	290·0	894·6	1184·6	81·3	4·951	·2020	·464	1·612
90	320·3	290·8	894·0	1184·8	81·3	4·898	·2042	·465	1·611
91	321·1	291·6	893·4	1185·0	81·4	4·846	·2063	·466	1·610
92	321·9	292·3	892·9	1185·2	81·4	4·795	·2085	·467	1·610
93	322·7	293·1	892·3	1185·4	81·5	4·746	·2107	·468	1·609
94	323·5	294·0	891·6	1185·6	81·5	4·699	·2128	·469	1·608
95	324·3	294·9	890·9	1185·8	81·5	4·653	·2149	·470	1·607
96	325·1	295·5	890·5	1186·0	81·6	4·607	·2170	·471	1·606
97	325·8	296·4	889·8	1186·2	81·6	4·562	·2192	·472	1·605
98	326·5	297·1	889·2	1186·3	81·7	4·517	·2214	·473	1·604
99	327·2	297·9	888·6	1186·5	81·7	4·474	·2235	·474	1·603
100	327·9	298·6	888·1	1186·7	81·7	4·433	·2256	·475	1·603
101	328·7	299·4	887·5	1186·9	81·8	4·392	·2277	·476	1·602
102	329·4	300·1	887·0	1187·1	81·8	4·351	·2298	·477	1·601
103	330·1	300·8	886·4	1187·2	81·9	4·310	·2320	·478	1·600
104	330·8	301·4	885·9	1187·3	81·9	4·270	·2341	·479	1·600
105	331·5	302·2	885·3	1187·5	81·9	4·231	·2363	·480	1·599
106	332·2	302·9	884·8	1187·7	82·0	4·194	·2384	·480	1·598
107	333·0	303·6	884·2	1187·8	82·0	4·156	·2406	·481	1·597
108	333·7	304·3	883·7	1188·0	82·0	4·120	·2427	·482	1·596
109	334·4	305·0	883·1	1188·1	82·1	4·085	·2448	·483	1·596
110	335·1	305·7	882·6	1188·3	82·1	4·050	·2469	·484	1·595
111	335·7	306·4	882·0	1188·4	82·1	4·016	·2490	·485	1·594
112	336·3	307·1	881·5	1188·6	82·2	3·982	·2511	·486	1·594
113	337·0	307·8	880·9	1188·7	82·2	3·948	·2533	·487	1·593
114	337·7	308·5	880·3	1188·8	82·2	3·914	·2555	·488	1·592
115	338·4	309·2	879·8	1189·0	82·3	3·880	·2577	·488	1·591
116	339·0	309·9	879·2	1189·1	82·3	3·848	·2598	·489	1·591
117	339·6	310·6	878·7	1189·3	82·3	3·816	·2620	·490	1·590
118	340·2	311·3	878·1	1189·4	82·3	3·785	·2642	·491	1·589
119	340·8	311·9	877·7	1189·6	82·4	3·754	·2664	·492	1·589
120	341·4	312·5	877·2	1189·7	82·4	3·724	·2685	·492	1·588

Fahrenheit Units.

p	t F	S	L	H	$E=\frac{Pu}{J}$	v	δ	ϕ_ω	ϕ_s
121	342·0	313·1	876·7	1189·8	82·4	3·695	·2706	·493	1·587
122	342·6	313·7	876·2	1189·9	82·5	3·667	·2727	·494	1·587
123	343·2	314·3	875·8	1190·1	82·5	3·639	·2748	·495	1·586
124	343·8	314·9	875·3	1190·2	82·5	3·611	·2769	·496	1·585
125	344·4	315·5	874·8	1190·3	82·6	3·584	·2790	·496	1·585
126	345·0	316·1	874·3	1190·4	82·6	3·557	·2811	·497	1·584
127	345·6	316·7	873·9	1190·6	82·6	3·530	·2832	·498	1·583
128	346·2	317·4	873·3	1190·7	82·7	3·504	·2853	·499	1·583
129	346·8	318·0	872·8	1190·8	82·7	3·478	·2875	·499	1·582
130	347·3	318·6	872·4	1191·0	82·7	3·452	·2897	·500	1·581
131	348·0	319·3	871·8	1191·1	82·7	3·427	·2918	·501	1·581
132	348·6	319·9	871·3	1191·2	82·8	3·402	·2939	·502	1·580
133	349·1	320·5	870·8	1191·3	82·8	3·379	·2960	·502	1·579
134	349·6	321·1	870·4	1191·5	82·8	3·355	·2981	·503	1·579
135	350·1	321·7	869·9	1191·6	82·8	3·331	·3002	·504	1·578
136	350·7	322·3	869·4	1191·7	82·9	3·308	·3023	·505	1·578
137	351·3	322·9	868·9	1191·8	82·9	3·285	·3044	·505	1·577
138	351·9	323·4	868·5	1191·9	82·9	3·263	·3065	·506	1·577
139	352·5	324·0	868·1	1192·1	82·9	3·241	·3086	·507	1·576
140	353·0	324·6	867·6	1192·2	83·0	3·219	·3107	·508	1·575
141	353·5	325·2	867·1	1192·3	83·0	3·187	·3139	·508	1·575
142	354·0	325·8	866·6	1192·4	83·0	3·173	·3150	·509	1·574
143	354·5	326·4	866·1	1192·5	83·0	3·154	·3171	·509	1·574
144	355·1	326·9	865·7	1192·6	83·1	3·133	·3192	·510	1·573
145	355·6	327·5	865·2	1192·7	83·1	3·112	·3213	·511	1·573
146	356·2	328·1	864·7	1192·8	83·1	3·091	·3235	·512	1·572
147	356·8	328·7	864·2	1192·9	83·2	3·071	·3256	·512	1·572
148	357·3	329·3	863·8	1193·1	83·2	3·051	·3277	·513	1·571
149	357·9	329·8	863·4	1193·2	83·2	3·032	·3298	·514	1·571
150	358·5	330·4	862·9	1193·3	83·2	3·013	·3319	·514	1·570
151	359·0	330·9	862·5	1193·4	83·3	2·994	·3340	·515	1·569
152	359·5	331·5	862·0	1193·5	83·3	2·975	·3361	·516	1·569
153	360·1	332·1	861·5	1193·6	83·3	2·956	·3382	·517	1·568
154	360·6	332·6	861·1	1193·7	83·3	2·937	·3404	·517	1·568
155	361·1	333·2	860·6	1193·8	83·4	2·919	·3426	·518	1·567
156	361·6	333·6	860·3	1193·9	83·4	2·902	·3446	·519	1·567
157	362·1	334·2	859·8	1194·0	83·4	2·885	·3467	·519	1·566
158	362·5	334·7	859·4	1194·1	83·4	2·868	·3488	·520	1·566
159	363·0	335·2	859·0	1194·2	83·4	2·851	·3508	·520	1·565
160	363·5	335·7	858·6	1194·3	83·5	2·834	·3529	·521	1·565
161	364·0	336·2	858·2	1194·4	83·5	2·817	·3550	·522	1·564
162	364·4	336·7	857·8	1194·5	83·5	2·800	·3570	·522	1·564
163	364·9	337·2	857·4	1194·6	83·5	2·784	·3591	·523	1·563
164	365·4	337·7	857·0	1194·7	83·5	2·768	·3612	·524	1·563
165	365·9	338·2	856·6	1194·8	83·6	2·752	·3633	·524	1·562
166	366·4	338·7	856·2	1194·9	83·6	2·736	·3654	·525	1·562
167	366·8	339·2	855·8	1195·0	83·6	2·721	·3675	·525	1·562
168	367·4	339·7	855·4	1195·1	83·6	2·706	·3696	·526	1·561
169	367·8	340·2	855·0	1195·2	83·6	2·691	·3717	·527	1·561
170	368·3	340·7	854·6	1195·3	83·6	2·676	·3738	·527	1·560

Fahrenheit Units.

p	tF	S	L	H	$E=\frac{Pu}{J}$	v	δ	ϕ_ω	φ_s
171	368·8	341·1	854·3	1195·4	83·7	2·661	·3759	·528	1·560
172	369·3	341·6	853·9	1195·5	83·7	2·646	·3780	·529	1·559
173	369·7	342·1	853·5	1195·6	83·7	2·631	·3801	·529	1·559
174	370·2	342·6	853·1	1195·7	83·7	2·616	·3822	·530	1·558
175	370·7	343·1	852·7	1195·8	83·7	2·601	·3844	·530	1·558
176	371·1	343·6	852·2	1195·8	83·7	2·587	·3865	·531	1·557
177	371·6	344·1	851·8	1195·9	83·7	2·573	·3887	·532	1·557
178	372·1	344·5	851·5	1196·0	83·8	2·559	·3908	·532	1·556
179	372·5	345·0	851·1	1196·1	83·8	2·545	·3928	·533	1·556
180	373·0	345·5	850·7	1196·2	83·8	2·532	·3950	·533	1·555
181	373·4	346·0	850·3	1196·3	83·8	2·519	·3970	·534	1·555
182	373·9	346·5	849·9	1196·4	83·8	2·506	·3990	·534	1·554
183	374·4	347·0	849·5	1196·5	83·8	2·493	·4010	·535	1·554
184	374·8	347·5	849·1	1196·6	83·8	2·480	·4031	·536	1·553
185	375·3	348·0	848·7	1196·7	83·9	2·467	·4052	·536	1·553
186	375·7	348·5	848·3	1196·8	83·9	2·455	·4072	·537	1·552
187	376·2	348·9	847·9	1196·8	83·9	2·443	·4093	·538	1·552
188	376·6	349·4	847·5	1196·9	83·9	2·431	·4114	·538	1·551
189	377·1	349·9	847·1	1197·0	84·0	2·419	·4134	·539	1·551
190	377·5	350·4	846·6	1197·0	84·0	2·407	·4155	·539	1·551
191	377·9	350·8	846·3	1197·1	84·0	2·395	·4175	·540	1·550
192	378·3	351·2	846·0	1197·2	84·1	2·383	·4196	·540	1·550
193	378·8	351·7	845·5	1197·2	84·1	2·371	·4217	·541	1·549
194	379·2	352·2	845·1	1197·3	84·1	2·359	·4238	·541	1·549
195	379·7	352·7	844·7	1197·4	84·2	2·347	·4259	·542	1·549
196	380·2	353·1	844·4	1197·5	84·2	2·336	·4280	·542	1·548
197	380·6	353·5	844·1	1197·6	84·2	2·325	·4301	·543	1·548
198	381·0	353·9	843·8	1197·7	84·2	2·314	·4322	·543	1·547
199	381·5	354·4	843·4	1197·8	84·2	2·303	·4343	·544	1·547
200	381·9	354·9	842·9	1197·8	84·3	2·292	·4364	·544	1·546
201	382·3	355·3	842·6	1197·9	84·3	2·281	·4385	·545	1·546
202	382·7	355·8	842·2	1198·0	84·3	2·270	·4406	·546	1·546
203	383·1	356·2	841·9	1198·1	84·3	2·259	·4427	·546	1·545
204	383·5	356·6	841·6	1198·2	84·3	2·248	·4448	·546	1·545
205	384·0	357·1	841·1	1198·2	84·3	2·238	·4468	·547	1·544
206	384·4	357·6	840·7	1198·3	84·4	2·228	·4489	·548	1·544
207	384·8	358·0	840·4	1198·4	84·4	2·218	·4510	·548	1·544
208	385·2	358·4	840·1	1198·5	84·4	2·208	·4531	·549	1·543
209	385·6	358·8	839·8	1198·6	84·4	2·198	·4551	·549	1·543
210	386·0	359·3	839·3	1198·6	84·4	2·188	·4571	·550	1·542
211	386·4	359·7	839·0	1198·7	84·4	2·178	·4592	·550	1·542
212	386·8	360·1	838·7	1198·8	84·4	2·168	·4613	·551	1·542
213	387·2	360·5	838·3	1198·8	84·4	2·158	·4634	·551	1·541
214	387·6	360·9	838·0	1198·9	84·5	2·148	·4655	·552	1·541
215	387·9	361·3	837·7	1199·0	84·5	2·138	·4676	·552	1·541
216	388·3	361·7	837·3	1199·0	84·5	2·128	·4697	·552	1·540
217	388·7	362·1	837·0	1199·1	84·5	2·119	·4718	·553	1·540
218	389·1	362·6	836·6	1199·2	84·5	2·110	·4739	·553	1·539
219	389·5	363·0	836·2	1199·2	84·5	2·101	·4759	·554	1·539
220	389·9	363·4	835·9	1199·3	84·5	2·092	·4780	·554	1·539

Fahrenheit Units.

p	t°F	S	L	H	$=\frac{Pu}{J}$	v	δ	ϕ_ω	ϕ_s
221	390·2	363·8	835·5	1199·3	84·6	2·083	·4801	·555	1·538
222	390·6	364·2	835·2	1199·4	84·6	2·074	·4822	·555	1·538
223	390·9	364·6	834·9	1199·5	84·6	2·065	·4843	·555	1·538
224	391·3	365·0	834·5	1199·5	84·6	2·056	·4864	·556	1·537
225	391·7	365·4	834·2	1199·6	84·6	2·047	·4885	·557	1·537
226	392·1	365·7	833·9	1199·6	84·6	2·038	·4906	·557	1·536
227	392·5	366·1	833·6	1199·7	84·6	2·029	·4928	·558	1·536
228	392·8	366·5	833·2	1199·7	84·6	2·020	·4949	·558	1·536
229	393·2	366·9	832·9	1199·8	84·6	2·012	·4970	·558	1·535
230	393·6	367·2	832·7	1199·9	84·7	2·004	·4990	·559	1·535
231	394·0	367·6	832·3	1199·9	84·7	1·996	·5010	·559	1·535
232	394·3	368·0	832·0	1200·0	84·7	1·988	·5030	·560	1·534
233	394·7	368·4	831·6	1200·0	84·7	1·980	·5051	·560	1·534
234	395·0	368·8	831·3	1200·1	84·7	1·972	·5072	·561	1·534
235	395·4	369·2	830·9	1200·1	84·7	1·964	·5093	·561	1·533
236	395·8	369·6	830·6	1200·2	84·7	1·956	·5114	·562	1·533
237	396·2	370·0	830·2	1200·2	84·7	1·948	·5135	·562	1·532
238	396·5	370·4	829·9	1200·3	84·7	1·940	·5156	·562	1·532
239	396·9	370·8	829·6	1200·4	84·7	1·932	·5177	·563	1·532
240	397·3	371·1	829·3	1200·4	84·7	1·924	·5198	·563	1·531
241	397·6	371·5	829·0	1200·5	84·8	1·916	·5219	·564	1·531
242	398·0	371·9	828·6	1200·5	84·8	1·908	·5240	·564	1·531
243	398·3	372·2	828·4	1200·6	84·8	1·901	·5261	·565	1·530
244	398·7	372·6	828·0	1200·6	84·8	1·893	·5282	·565	1·530
245	399·0	373·0	827·7	1200·7	84·8	1·885	·5303	·565	1·530
246	399·4	373·4	827·3	1200·7	84·8	1·877	·5324	·566	1·529
247	399·7	373·7	827·1	1200·8	84·8	1·870	·5345	·566	1·529
248	400·1	374·1	826·7	1200·8	84·8	1·863	·5366	·567	1·529
249	400·4	374·4	826·5	1200·9	84·8	1·856	·5387	·567	1·528
250	400·8	374·8	826·1	1200·9	84·8	1·849	·5408	·568	1·528

SATURATED STEAM TABLE (Centigrade Units).

Absolute pressure lbs. per sq. in.	Temperature in degrees.	Sensible Heat.	Latent Heat.	Total Heat.	External Work.	Entropy of Water.	Total Entropy of Steam.
p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
·089	0	0	596·4	596·4	30·0	0	2·185
·1	1·95	1·94	595·3	597·2	30·2	·007	2·172
·2	11·7	11·7	590·0	601·7	31·3	·042	2·114
·3	18·3	18·2	586·3	604·5	32·1	·065	2·080
·4	22·8	22·9	583·6	606·5	32·8	·081	2·054
·5	26·4	26·2	582·0	608·2	33·2	·096	2·037
·6	29·6	29·6	580·0	609·6	33·4	·105	2·022
·7	32·3	32·2	578·5	610·7	33·7	·112	2·007
·8	34·7	34·6	577·2	611·8	33·9	·119	1·996
·9	37·0	36·8	576·0	612·8	34·1	·127	1·986
1·0	38·8	38·6	575·0	613·6	34·3	·133	1·977
1·1	40·6	40·4	574·0	614·4	34·4	·139	1·968
1·2	42·2	42·0	573·1	615·1	34·6	·144	1·961
1·3	43·8	43·6	572·2	615·8	34·8	·148	1·954
1·4	45·2	45·0	571·4	616·4	34·9	·152	1·948
1·5	46·6	46·4	570·5	617·0	35·1	·157	1·943
1·6	47·8	47·7	569·8	617·5	35·2	·161	1·937
1·7	49·1	49·3	568·7	618·0	35·3	·165	1·932
1·8	50·2	50·4	568·1	618·5	35·4	·169	1·927
1·9	51·3	51·1	568·0	619·1	35·6	·172	1·923
2·0	52·3	52·1	567·5	619·6	35·7	·175	1·918
2·5	56·8	56·7	564·8	621·5	36·2	·188	1·900
3·0	60·8	60·1	563·3	623·4	36·7	·201	1·885
3·5	64·2	63·9	560·8	624·7	37·1	·211	1·873
4·0	67·2	67·0	558·9	625·9	37·4	·219	1·863
4·5	70·0	69·6	557·5	627·1	37·6	·227	1·852
5·0	72·4	72·1	556·0	628·1	37·8	·234	1·844
6	76·7	76·3	553·6	629·9	38·2	·246	1·828
7	80·4	80·0	551·4	631·4	38·6	·257	1·816
8	83·9	83·3	549·4	632·7	38·9	·267	1·805
9	86·8	86·3	557·5	633·8	39·2	·275	1·796
10	89·3	89·1	545·8	634·9	39·4	·283	1·788
11	92·0	91·7	544·5	636·0	39·6	·291	1·780
12	94·5	94·2	542·8	637·0	39·8	·297	1·773
13	96·7	96·3	541·4	637·7	40·1	·303	1·767
14	98·7	98·3	540·2	638·5	40·3	·308	1·762
14·7	100	99·6	539·3	638·9	40·4	·312	1·758
15	100·7	100·2	539·1	639·3	40·5	·314	1·756
16	102·4	102·1	537·8	639·9	40·7	·319	1·750
17	104·0	103·7	536·8	640·5	40·9	·324	1·747
18	105·5	105·4	535·7	641·1	41·0	·327	1·743
19	107·0	107·1	534·5	641·6	41·1	·331	1·738
20	108·5	108·7	533·4	642·1	41·3	·335	1·735

Centigrade Units.

p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
21	110·0	110·2	532·4	642·6	41·4	·339	1·730
22	111·5	111·7	531·4	643·1	41·5	·343	1·727
23	112·9	113·2	530·4	643·6	41·7	·346	1·723
24	114·2	114·4	529·7	644·1	41·8	·350	1·719
25	115·4	115·7	528·8	644·5	41·9	·353	1·716
26	116·7	116·9	528·1	645·0	42·0	·357	1·712
27	117·8	118·2	527·2	645·4	42·1	·359	1·709
28	118·9	119·4	526·4	645·8	42·2	·362	1·707
29	120·1	120·6	525·5	646·1	42·3	·365	1·703
30	121·2	121·7	524·7	646·4	42·3	·368	1·700
31	122·2	122·7	524·1	646·8	42·4	·371	1·698
32	123·2	123·8	523·4	647·2	42·5	·374	1·695
33	124·2	124·7	522·9	647·6	42·6	·377	1·692
34	125·2	125·7	522·2	647·9	42·7	·379	1·690
35	126·1	126·7	521·4	648·1	42·8	·381	1·687
36	127·1	127·7	520·7	648·4	42·9	·384	1·685
37	128·0	128·5	520·3	648·8	43·0	·386	1·684
38	128·9	129·5	519·5	649·0	43·0	·388	1·681
39	129·7	130·3	519·0	649·3	43·1	·390	1·679
40	130·6	131·2	518·4	649·6	43·1	·393	1·677
41	131·4	132·1	517·8	649·9	43·2	·395	1·675
42	132·2	132·9	517·3	650·2	43·2	·397	1·673
43	133·1	133·7	516·7	650·4	43·3	·399	1·671
44	133·9	134·6	516·0	650·6	43·4	·401	1·669
45	134·7	135·3	515·5	650·8	43·5	·403	1·667
46	135·4	136·2	515·0	651·2	43·6	·405	1·665
47	136·1	136·9	514·5	651·4	43·6	·407	1·664
48	136·8	137·7	513·9	651·6	43·7	·409	1·662
49	137·6	138·5	513·4	651·9	43·7	·410	1·660
50	138·3	139·2	512·9	652·1	43·8	·412	1·659
51	139·0	140·0	512·2	652·2	43·8	·414	1·657
52	139·7	140·7	511·8	652·5	43·9	·416	1·656
53	140·4	141·4	511·2	652·6	43·9	·417	1·654
54	141·1	142·1	510·7	652·8	44·0	·419	1·652
55	141·7	142·7	510·3	653·0	44·0	·421	1·651
56	142·4	143·4	509·8	653·2	44·1	·422	1·650
57	143·0	144·0	509·4	653·4	44·1	·424	1·649
58	143·6	144·6	509·0	653·6	44·1	·425	1·648
59	144·2	145·3	508·5	653·8	44·2	·427	1·646
60	145·2	145·9	508·1	654·0	44·2	·428	1·645
61	145·5	146·6	507·6	654·2	44·2	·430	1·643
62	146·1	147·2	507·1	654·3	44·3	·432	1·642
63	146·7	147·8	506·6	654·4	44·3	·433	1·641
64	147·3	148·4	506·2	654·6	44·3	·434	1·640
65	147·8	149·0	505·8	654·8	44·4	·436	1·638
66	148·4	149·6	505·3	654·9	44·4	·437	1·637
67	148·9	150·2	504·9	655·1	44·4	·439	1·636
68	149·5	150·7	504·6	655·3	44·5	·440	1·635
69	150·0	151·3	504·1	655·4	44·5	·441	1·634
70	150·5	151·8	503·8	655·6	44·6	·442	1·632

Centigrade Units.

p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
71	151·0	152·4	503·3	655·7	44·6	·443	1·631
72	151·5	152·8	503·0	655·8	44·6	·445	1·630
73	152·0	153·4	502·6	656·0	44·7	·446	1·629
74	152·5	153·9	502·3	656·2	44·7	·447	1·628
75	153·0	154·5	501·9	656·4	44·7	·448	1·627
76	153·5	155·0	501·4	656·4	44·8	·449	1·626
77	154·0	155·4	501·1	656·5	44·8	·450	1·625
78	154·5	155·9	500·7	656·6	44·8	·452	1·624
79	155·0	156·4	500·4	656·8	44·8	·453	1·623
80	155·6	157·0	500·0	657·0	44·9	·454	1·622
81	156·1	157·4	499·7	657·1	44·9	·455	1·621
82	156·5	157·9	499·4	657·3	44·9	·456	1·620
83	156·9	158·3	499·1	657·4	45·0	·457	1·619
84	157·4	158·8	498·7	657·5	45·0	·458	1·618
85	157·8	159·3	498·3	657·6	45·0	·460	1·617
86	158·3	159·7	498·0	657·7	45·0	·461	1·616
87	158·8	160·2	497·6	657·8	45·1	·462	1·615
88	159·3	160·6	497·4	658·0	45·1	·463	1·613
89	159·7	161·1	497·0	658·1	45·1	·464	1·612
90	160·2	161·5	496·8	658·2	45·1	·465	1·611
91	160·6	162·0	496·4	658·4	45·2	·466	1·610
92	161·1	162·4	496·1	658·5	45·2	·467	1·610
93	161·5	162·8	495·8	658·6	45·2	·468	1·609
94	161·9	163·3	495·4	658·7	45·2	·469	1·608
95	162·4	163·8	495·0	658·8	45·2	·470	1·607
96	162·8	164·2	494·7	658·9	45·3	·471	1·606
97	163·2	164·7	494·3	659·0	45·3	·472	1·605
98	163·6	165·0	494·1	659·1	45·3	·473	1·604
99	164·0	165·5	493·7	659·2	45·3	·474	1·603
100	164·4	165·9	493·4	659·3	45·4	·475	1·603
101	164·8	166·3	493·1	659·4	45·4	·476	1·602
102	165·2	166·7	492·8	659·5	45·4	·477	1·601
103	165·6	167·1	492·5	659·6	45·5	·478	1·600
104	166·0	167·4	492·3	659·7	45·5	·479	1·600
105	166·4	167·9	491·8	659·7	45·5	·480	1·599
106	166·8	168·3	491·5	659·8	45·6	·480	1·598
107	167·3	168·6	491·3	659·9	45·6	·481	1·597
108	167·6	169·0	491·0	660·0	45·6	·482	1·596
109	168·0	169·4	490·7	660·1	45·6	·483	1·596
110	168·4	169·8	490·4	660·2	45·6	·484	1·595
111	168·8	170·2	490·1	660·3	45·6	·485	1·594
112	169·1	170·6	489·8	660·4	45·6	·486	1·594
113	169·5	171·0	489·4	660·4	45·7	·487	1·593
114	169·8	171·4	489·1	660·5	45·7	·488	1·592
115	170·3	171·8	488·7	660·5	45·7	·488	1·591
116	170·6	172·2	488·4	660·6	45·7	·489	1·591
117	170·9	172·5	488·2	660·7	45·7	·490	1·590
118	171·2	172·9	487·9	660·8	45·7	·491	1·589
119	171·6	173·3	487·6	660·9	45·7	·492	1·589
120	171·9	173·6	487·4	661·0	45·8	·492	1·588

Centigrade Units.

p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
121	172·2	173·9	487·1	661·0	45·8	·493	1·587
122	172·6	174·3	486·7	661·0	45·8	·494	1·587
123	172·9	174·6	486·5	661·1	45·8	·495	1·586
124	173·2	175·0	486·2	661·2	45·8	·496	1·585
125	173·6	175·3	486·0	661·3	45·8	·496	1·585
126	173·9	175·6	485·7	661·3	45·9	·497	1·584
127	174·2	176·0	485·4	661·4	45·9	·498	1·583
128	174·6	176·3	485·1	661·4	45·9	·499	1·583
129	174·9	176·7	484·8	661·5	46·0	·499	1·582
130	175·2	177·0	484·6	661·6	46·0	·500	1·581
131	175·6	177·4	484·3	661·7	46·0	·501	1·581
132	175·9	177·7	484·1	661·8	46·0	·502	1·580
133	176·2	178·1	483·7	661·8	46·0	·502	1·579
134	176·5	178·4	483·5	661·9	46·0	·503	1·579
135	176·7	178·7	483·3	662·0	46·0	·504	1·578
136	177·1	179·1	483·0	662·1	46·1	·505	1·578
137	177·4	179·4	482·7	662·1	46·1	·505	1·577
138	177·7	179·7	482·5	662·2	46·1	·506	1·577
139	178·1	180·0	482·3	662·3	46·1	·507	1·576
140	178·3	180·3	482·1	662·4	46·1	·508	1·575
141	178·6	180·7	481·7	662·4	46·1	·508	1·575
142	178·9	181·0	481·5	662·5	46·1	·509	1·574
143	179·2	181·3	481·2	662·5	46·2	·509	1·574
144	179·5	181·6	480·9	662·5	46·2	·510	1·573
145	179·8	182·0	480·6	662·6	46·2	·511	1·573
146	180·1	182·3	480·3	662·6	46·2	·512	1·572
147	180·4	182·6	480·1	662·7	46·2	·512	1·572
148	180·7	183·0	479·8	662·8	46·2	·513	1·571
149	181·1	183·2	479·7	662·9	46·2	·514	1·571
150	181·4	183·6	479·4	663·0	46·3	·514	1·570
151	181·7	183·8	479·2	663·0	46·3	·515	1·569
152	182·0	184·2	478·8	663·0	46·3	·516	1·569
153	182·3	184·5	478·6	663·1	46·3	·517	1·568
154	182·6	184·8	478·4	663·2	46·2	·517	1·568
155	182·8	185·1	478·1	663·2	46·3	·518	1·567
156	183·1	185·3	477·9	663·2	46·3	·519	1·567
157	183·4	185·7	477·6	663·3	46·3	·519	1·566
158	183·6	185·9	477·5	663·4	46·3	·520	1·566
159	183·9	186·2	477·3	663·5	46·4	·520	1·565
160	184·2	186·5	477·1	663·6	46·4	·521	1·565
161	184·5	186·8	476·8	663·6	46·4	·522	1·564
162	184·7	187·1	476·5	663·6	46·4	·522	1·564
163	185·0	187·3	476·4	663·7	46·4	·523	1·563
164	185·2	187·6	476·1	663·7	46·4	·524	1·563
165	185·5	187·9	475·8	663·7	46·4	·524	1·562
166	185·8	188·2	475·6	663·8	46·4	·525	1·562
167	186·0	188·4	475·4	663·8	46·4	·525	1·562
168	186·4	188·7	475·2	663·9	46·4	·526	1·561
169	186·6	189·0	475·0	664·0	46·5	·527	1·561
170	186·9	189·3	474·7	664·0	46·5	·527	1·560

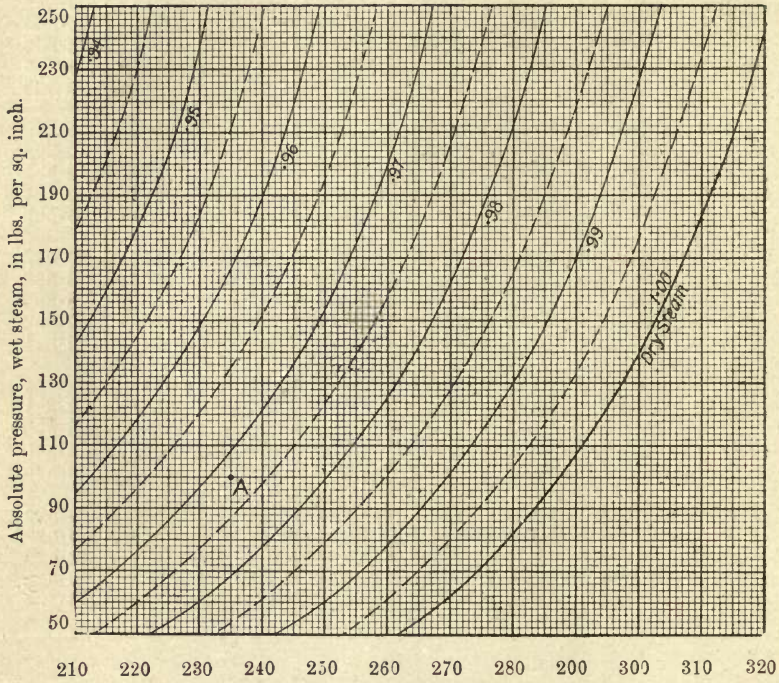
Centigrade Units.

p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
171	187·2	189·5	474·6	664·1	46·5	·528	1·560
172	187·4	189·8	474·3	664·1	46·5	·529	1·559
173	187·6	190·1	474·1	664·2	46·5	·529	1·559
174	187·9	190·3	473·9	664·2	46·5	·530	1·558
175	188·2	190·6	473·7	664·3	46·6	·530	1·558
176	188·4	190·9	473·5	664·4	46·6	·531	1·557
177	188·7	191·2	473·2	664·4	46·6	·532	1·557
178	189·0	191·4	473·1	664·5	46·6	·532	1·556
179	189·2	191·7	472·8	664·5	46·6	·533	1·556
180	189·5	191·9	472·7	664·6	46·6	·533	1·555
181	189·7	192·2	472·4	664·6	46·6	·534	1·555
182	189·9	192·5	472·1	664·6	46·6	·534	1·554
183	190·2	192·8	471·9	664·7	46·6	·535	1·554
184	190·5	193·1	471·6	664·7	46·6	·536	1·553
185	190·7	193·3	471·5	664·8	46·6	·536	1·553
186	191·0	193·6	471·2	664·8	46·6	·537	1·552
187	191·2	193·8	471·1	664·9	46·7	·538	1·552
188	191·5	194·1	469·8	664·9	46·7	·538	1·551
189	191·7	194·4	469·6	665·0	46·7	·539	1·551
190	192·0	194·7	469·3	665·0	46·7	·539	1·551
191	192·2	194·9	469·2	665·1	46·7	·540	1·550
192	192·4	195·1	469·0	665·1	46·7	·540	1·550
193	192·7	195·4	469·8	665·2	46·7	·541	1·549
194	192·9	195·7	469·5	665·2	46·8	·541	1·549
195	193·2	196·0	469·2	665·2	46·8	·542	1·549
196	193·5	196·2	469·1	665·3	46·8	·542	1·548
197	193·7	196·4	468·9	665·3	46·8	·543	1·548
198	193·9	196·6	468·8	665·4	46·8	·543	1·547
199	194·2	196·9	468·5	665·4	46·8	·544	1·547
200	194·4	197·1	468·3	665·4	46·8	·544	1·546
201	194·6	197·4	468·1	665·5	46·8	·545	1·546
202	194·8	197·7	467·8	665·5	46·8	·546	1·546
203	195·1	197·9	467·7	665·6	46·8	·546	1·545
204	195·3	198·1	467·5	665·6	46·8	·546	1·545
205	195·6	198·4	467·2	665·6	46·8	·547	1·544
206	195·8	198·7	467·0	665·7	46·9	·548	1·544
207	196·0	198·9	466·8	665·7	46·9	·548	1·544
208	196·2	199·1	466·7	665·8	46·9	·549	1·543
209	196·4	199·3	466·5	665·8	46·9	·549	1·543
210	196·7	199·6	466·3	665·9	46·9	·550	1·542
211	196·9	199·8	466·2	666·0	46·9	·550	1·542
212	197·1	200·0	466·0	666·0	46·9	·551	1·542
213	197·3	200·3	465·7	666·0	46·9	·551	1·541
214	197·6	200·5	465·5	666·0	46·9	·552	1·541
215	197·7	200·7	465·4	666·1	46·9	·552	1·541
216	198·0	200·9	465·2	666·1	46·9	·552	1·540
217	198·2	201·2	464·9	666·1	46·9	·553	1·540
218	198·4	201·4	464·7	666·1	46·9	·553	1·539
219	198·6	201·7	464·5	666·2	47·0	·554	1·539
220	198·8	201·9	464·3	666·2	47·0	·554	1·539

Centigrade Units.

p	$t°c$	S	L	H	E	ϕ_ω	ϕ_s
221	199·0	202·1	464·1	666·2	47·0	·555	1·539
222	199·2	202·3	463·9	666·2	47·0	·555	1·538
223	199·4	202·5	463·8	666·3	47·0	·555	1·538
224	199·6	202·8	463·5	666·3	47·0	·556	1·537
225	199·8	203·0	463·3	666·3	47·0	·557	1·537
226	200·1	203·2	463·2	666·4	47·0	·557	1·536
227	200·3	203·4	463·0	666·4	47·0	·558	1·536
228	200·4	203·6	462·8	666·4	47·0	·558	1·536
229	200·7	203·8	462·7	666·5	47·0	·558	1·535
230	200·9	204·0	462·5	666·5	47·1	·559	1·535
231	201·1	204·2	462·4	666·6	47·1	·559	1·535
232	201·3	204·4	462·2	666·6	47·1	·560	1·534
233	201·5	204·7	461·9	666·6	47·1	·560	1·534
234	201·7	204·9	461·8	666·7	47·1	·561	1·534
235	201·9	205·1	461·6	666·7	47·1	·561	1·533
236	202·1	205·3	461·4	666·7	47·1	·562	1·533
237	202·3	205·6	461·2	666·8	47·1	·562	1·532
238	202·5	205·8	461·0	666·8	47·1	·562	1·532
239	202·7	206·0	460·8	666·8	47·1	·563	1·532
240	203·0	206·2	460·7	666·9	47·1	·563	1·531
241	203·1	206·4	460·5	666·9	47·1	·564	1·531
242	203·3	206·6	460·3	666·9	47·1	·564	1·531
243	203·5	206·8	460·2	667·0	47·1	·565	1·530
244	203·7	207·0	460·0	667·0	47·1	·565	1·530
245	203·9	207·2	459·8	667·0	47·1	·565	1·530
246	204·1	207·4	459·7	667·1	47·1	·566	1·529
247	204·3	207·6	459·5	667·1	47·1	·566	1·529
248	204·5	207·8	459·3	667·1	47·1	·567	1·529
249	204·7	208·0	459·2	667·2	47·1	·567	1·528
250	204·9	208·2	459·0	667·2	47·1	·568	1·528

STEAM DRYNESS CHART FOR USE WITH THROTTLING CALORIMETER.



Temperature Fahrenheit of Superheated Steam (t_s) in the Calorimeter at atmospheric pressure.

Method of Using the Chart.—Determine the inter-section of the horizontal line through the absolute pressure of the wet steam, and the vertical line through the temperature Fahrenheit of the steam in the calorimeter, and note the position of this point with regard to the curves on the chart. Thus, if wet steam at 100 lbs. per square inch absolute gave a temperature of 235 deg. Fah. in the calorimeter, the point of inter-section A is situated between the curves ·97 and ·975, its position indicating a dryness of ·972, the last digit being represented by the distance of A from the ·97 curve measured in a direction perpendicular to the curves.

SUPERHEATED STEAM.

Mean Specific Heat and Total Heat.—To obtain the total heat of superheated steam, it is necessary to obtain the total heat of saturated steam at the same pressure, and add to it the amount of heat required to raise the temperature of the steam from saturation temperature to the actual temperature of the superheated steam. The latter quantity of heat is given by the product of the *mean* specific heat and the difference between the actual and saturation temperatures.

As an example, determine the total heat of superheated steam at 180 lbs. per square inch absolute and 600 deg. Fah. The saturation temperature is 373 deg. Fah., hence the rise of temperature above saturation is 600 — 373 = 227 deg. At 180 lbs. and 600 deg. Fah. the mean specific heat given in the following table is ·538 ; hence the additional heat above the saturated condition is ·538 × 227 = 122·1 B.Th.U., and the total heat of the superheated steam is 122·1 + 1196·2 = 1318·3 B.Th.U. per lb. It may also be obtained by inserting the values for t, T and p in Callendar's equation for the total heat of steam (saturated and superheated) previously given. The number so obtained is 1319·3 B.Th.U. per lb., which is within one-tenth per cent of the value just obtained by the other method. In no case do the numbers obtained by the two methods differ by more than one-tenth per cent.

The mean specific heats in the accompanying table were obtained from the actual specific heats determined experimentally by Knoblauch and Jakob. These numbers at constant pressure were plotted on a temperature base, and the areas under the curves from saturation temperatures represented the heat added during the process of superheating up to any given temperature. This quantity of heat divided by the excess of the temperature of the superheated steam above that of saturation gives the mean specific heat Cm.

Specific Volume of Superheated Steam.—Callendar's equation

$$P\,[V + a - b] = R\,T$$

will give the specific volume of saturated or superheated steam. The following values may be used : b = ·01606, R = 86,

$$a = 1{\cdot}367\ \left(\frac{491{\cdot}6}{T}\right)^{\frac{10}{3}},$$

T = abs. temperature on the Fahrenheit scale, V = volume of 1 lb. steam in cubic feet, and P = pressure in lbs. per square foot.

Linde's equation is more often used. It is

$$P\,V = 85{\cdot}85\,T - P\,(1 + {\cdot}00000976\,P)\left(\frac{150{,}300{,}000}{T^3} - {\cdot}0833\right)$$

the units being the same as above. This equation also may be used for saturated as well as superheated steam.

MEAN SPECIFIC HEAT OF SUPERHEATED STEAM.

Temperature.		Absolute Pressure Lbs. per Square Inch.									
Fah.	Cen.	20	40	50	60	70	80	90	100	110	120
240	115·6	·468	..	..	..	..	..	..	..	..	..
260	126·7	·468	..	..	..	..	..	..	..	..	..
280	137·8	·468	·493	·510	..	..	..	..	..	..	..
300	148·9	·467	·491	·506	·520	..	..	..	..	..	..
320	160·0	·467	·489	·503	·516	·529	·544	·554	..	..	..
340	171·1	·467	·487	·500	·513	·524	·536	·548	·561	·576	·590
360	182·2	·467	·486	·498	·510	·521	·532	·543	·554	·567	·580
380	193·3	·467	·485	·496	·506	·517	·527	·538	·548	·559	·571
400	204·4	·467	·484	·494	·504	·514	·524	·533	·542	·552	·562
420	215·5	·467	·484	·493	·502	·511	·520	·528	·537	·546	·555
440	226·7	·467	·484	·492	·500	·508	·516	·524	·532	·540	·548
460	237·8	·467	·484	·491	·498	·506	·513	·520	·527	·535	·543
480	248·9	·467	·483	·490	·497	·504	·511	·517	·523	·530	·538
500	260·0	·467	·483	·490	·496	·503	·509	·515	·520	·526	·533
520	271·1	·467	·483	·489	·495	·501	·507	·512	·517	·523	·529
540	282·2	·467	·482	·488	·494	·500	·505	·510	·515	·520	·525
560	293·3	·468	·482	·488	·494	·499	·503	·508	·513	·517	·522
580	304·4	·468	·482	·487	·493	·498	·503	·507	·511	·515	·520
600	315·5	·468	·482	·487	·493	·497	·502	·506	·510	·514	·518
620	326·6	·469	·482	·487	·492	·496	·501	·505	·509	·513	·516
640	337·7	·469	·482	·487	·492	·496	·501	·504	·508	·512	·515
660	348·9	·470	·482	·487	·493	·497	·501	·504	·507	·511	·514
680	360·0	·471	·483	·488	·493	·497	·501	·504	·507	·511	·514
700	371·1	·472	·484	·488	·493	·497	·501	·504	·507	·511	·514
720	382·2	·473	·485	·489	·494	·498	·502	·505	·507	·511	·514
740	393·3	·474	·486	·490	·495	·499	·503	·506	·508	·511	·514
760	404·4	·476	·487	·492	·496	·500	·503	·506	·509	·512	·514

Mean Specific Heat of Superheated Steam—*Continued.*

Temperature.		Absolute Pressure Lbs. per Square Inch.									
Fah.	Cen.	130	140	150	160	170	180	190	200	210	220
240	115·6	..	..	..	..	..	..	..	..	..	..
260	126·7	..	..	..	..	..	..	..	..	..	..
280	137·8	..	..	..	..	..	..	..	..	..	..
300	148·9	..	..	..	..	..	..	..	..	..	..
320	160·0	..	..	..	..	..	..	..	..	..	..
340	171·1	..	..	..	..	..	..	..	..	..	..
360	182·2	·595	·609	·624	..	..	..	..	..	..	..
380	193·3	·585	·598	·612	·626	·642	·660	·671	·685	..	..
400	204·4	·575	·588	·601	·614	·627	·640	·652	·665	·673	·678
420	215·5	·566	·577	·588	·599	·610	·620	·632	·645	·651	·656
440	226·7	·558	·567	·577	·586	·596	·605	·615	·625	·630	·635
460	237·8	·551	·560	·567	·574	·583	·591	·599	·608	·613	·617
480	248·9	·545	·550	·557	·564	·571	·577	·584	·591	·596	·601
500	260·0	·539	·544	·550	·556	·562	·567	·573	·579	·584	·589
520	271·1	·534	·540	·545	·550	·555	·560	·565	·569	·574	·579
540	282·2	·530	·535	·540	·544	·549	·553	·557	·561	·566	·570
560	293·3	·527	·532	·536	·540	·544	·547	·551	·555	·559	·563
580	304·4	·524	·528	·532	·535	·539	·542	·546	·549	·553	·556
600	315·5	·522	·526	·529	·532	·535	·538	·541	·544	·547	·550
620	326·6	·520	·524	·527	·530	·533	·535	·538	·541	·544	·546
640	337·7	·519	·522	·525	·528	·531	·533	·536	·538	·541	·543
660	348·8	·518	·521	·524	·526	·529	·532	·534	·536	·539	·541
680	360·0	·517	·520	·523	·525	·528	·530	·533	·535	·538	·540
700	371·1	·516	·519	·522	·524	·527	·529	·532	·534	·537	·539
720	382·2	·516	·519	·522	·524	·526	·528	·531	·533	·536	·538
740	393·3	·516	·519	·521	·524	·526	·527	·530	·532	·535	·537
760	404·4	·517	·520	·521	·523	·525	·526	·529	·531	·534	·536

THERMAL CONDUCTIVITY AND EMISSIVITY.

The thermal conductivity k is the number of calories conducted per second across a slab of material 1 cm. thick and 1 sq. cm. sectional area when the difference of temperature of the opposite faces (which are perpendicular to the direction of flow) is 1 deg. Cen.

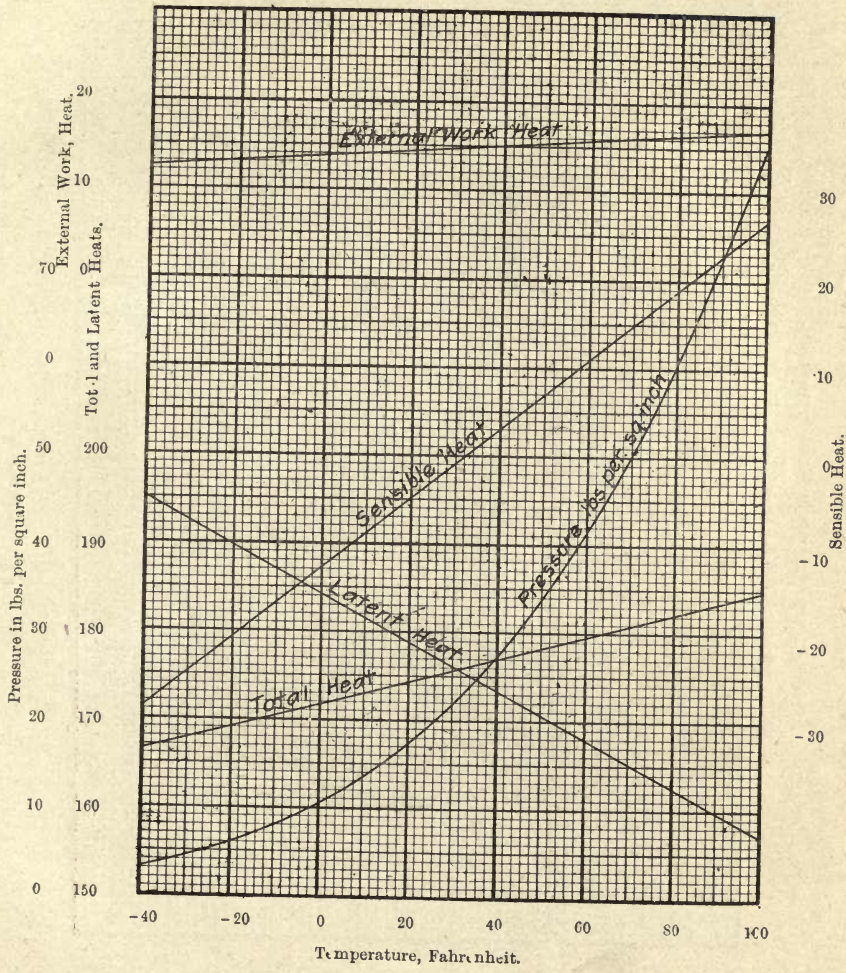
Material.	Conductivity k (mean).
Air at 0 deg. Cen.	·000052
Aluminium	·485
Asbestos Cardboard	·0006
Brass	·26
Carbonic Anhydride at 0 deg. Cen.	·000031
Copper	·91
Cork	·00013
Cotton Wool	·00004
Ebonite	·00042
Felt	·00009
Glass (Crown)	·0025
Glass (Flint)	·002
Gold	·70
Hydrogen at 0 deg. Cen.	·000319
Iron (Wrought)	·144
Iron (Cast)	·113
Lead	·083
Mahogany	·0005
Mercury	·018
Mica	·0018
Nickel	·14
Nitrogen at 0 deg. Cen.	·000052
Oxygen at 0 deg. Cen.	·000056
Paper	·0003
Pine	·0004
Porcelain	·0025
Platinum	·17
Sawdust	·00012
Silicate Cotton	·00019
Silver	1·00
Steel (1 per cent Carbon)	·108
Tin	·15
Water	·0014
Zinc	·264

The emissivity of a blackened copper surface in contact with the air is given by e in the following equation, and represents the heat units lost per second, per square centimetre per degree difference between the temperature centigrade of the copper and that of a blackened enclosure. The emissivity of a polished surface is about ·69 of that from the black surface.

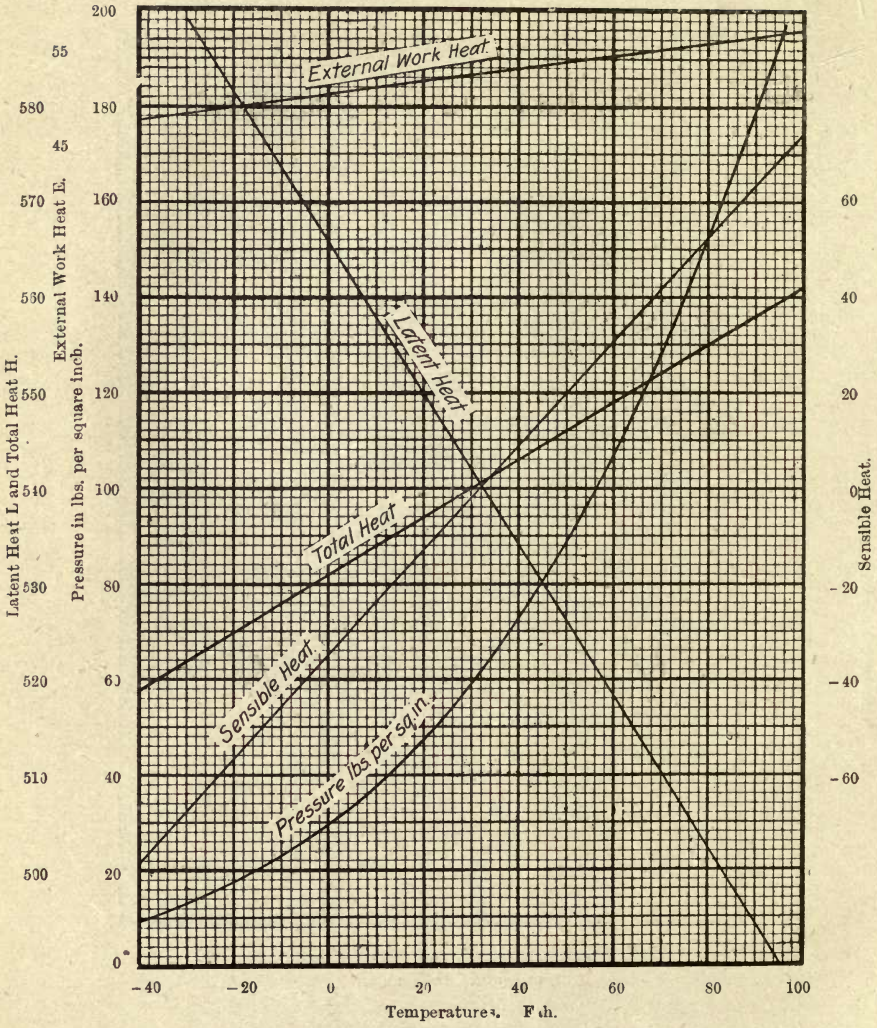
$$e = ·000238 + 3·06\frac{t}{10^6} - 2·6\left(\frac{t}{10000}\right)^2$$

t being the temperature difference on the Centigrade scale.

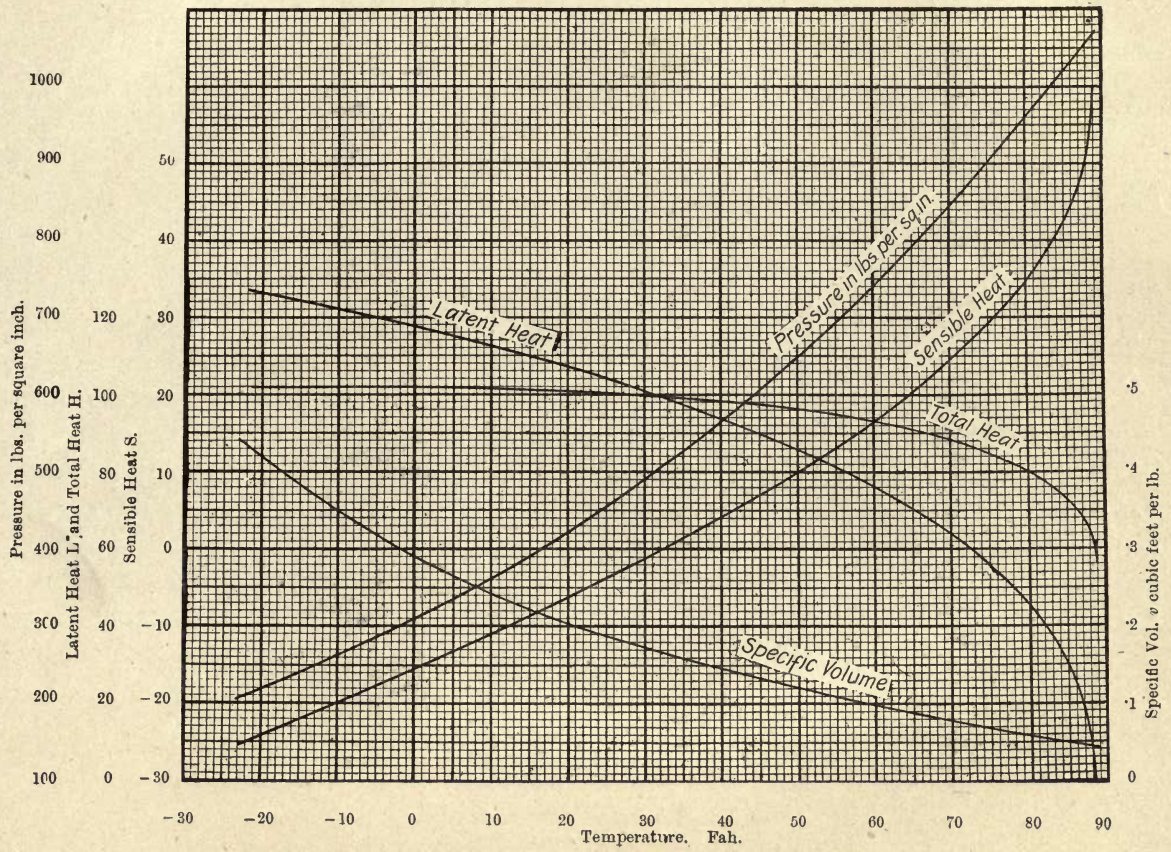
SULPHUR DIOXIDE CHART.



AMMONIA CHART.



CARBONIC ANHYDRIDE (CO_2) CHART.



MENSURATION

Triangle.—Area of triangle $= \frac{1}{2}$ base $\times$ perpendicular height.

$$= \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$$

Where a, b, and c are the lengths of three sides respectively, and s is their half sum or

$$s = \frac{a+b+c}{2.}$$

Trapezoid.—Area of trapezoid $= \left(\frac{a+b}{2}\right) d$

Where a and b are the lengths of the parallel sides respectively, and d their distance apart.

Quadrilateral.—Area A D B F (Fig. 1)

$$= \frac{A\,B}{2}\left(C\,D + E\,F\right)$$

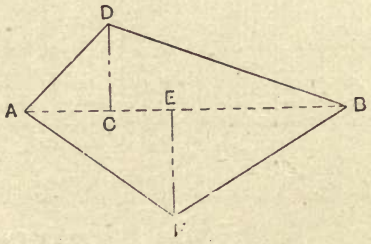


Fig. 1.

Parallelogram.—Area = base $\times$ perpendicular height.

MENSURATION.

Area of an Irregular Figure.—

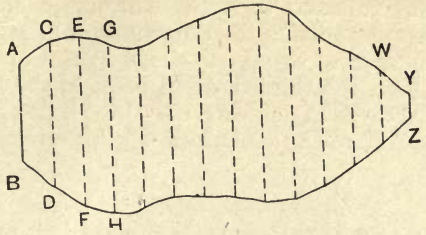


Fig. 2.

Divide the figure (Fig. 2) into a number of parallel strips of equal width, then area of figure =

$$\left(\frac{\text{first ordinate} + \text{last ordinate}}{2} + \text{sum of all other ordinates}\right) \times \text{width of a strip.}$$

$$= \left(\frac{A\,B + Y\,Z}{2} + C\,D + E\,F + + + + W\,X\right)\frac{l}{n}$$

Where l = length of figure perpendicular to strips, *i.e.*, distance between A B and Y Z, and n = number of strips.

Parabola (Fig. 3).—Area of segment C A D $= \frac{2}{3}$ C M N D

$= \frac{2}{3}$ C D $\times$ A B $= \frac{2}{3}$ area of circumscribing triangle C T D.

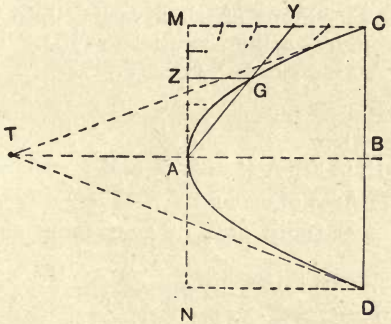


Fig. 3.

Area of A C M $= \frac{1}{3}$ C B $\times$ A B.

Volume of paraboloid of revolution = one-half that of the circumscribing cylinder.

Method of Describing a Parabola.—Draw the tangent N A M at the vertex A perpendicular to A B. Through C and D draw lines parallel with the axis, cutting the tangent at A in N and M. Divide A M into any number of equal parts (say 5) and divide M C in like manner. Join, say, the third division point in the latter to A, and through the third division point in A M, draw a line parallel with the axis and cutting A Y in G. Then G is a point on the parabola.

Hyperbola (Fig. 4).—

$$\text{Area of O A B C D} = \text{O A} \times \text{A B}\left(1 + \log_e \frac{\text{O D}}{\text{A B}}\right)$$

$$= \text{O A} \times \text{A B}\left(1 + \log_e \frac{\text{O A}}{\text{C D}}\right)$$

$$\text{Area of B C M} = \text{O A}\left(\text{B M} - \text{A B} \log_e \frac{\text{O A}}{\text{C D}}\right)$$

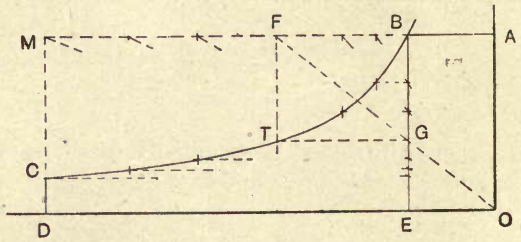


Fig. 4.

Method of Describing the Hyperbola.—Draw the axes O A, O D, and let B be a point on the curve which is given. Draw B E parallel to A O. Produce A B indefinitely and take at random points in A B produced, one of which is F. Join O F; it cuts B E in G. Draw through G a line parallel to O D. Through F draw a line parallel to A O, cutting T G in T. Then T is a point on the hyperbola.

Cycloid (Fig. 5).—

$$\text{Length of arc A P} = 2\sqrt{\text{A B} \times \text{A C}} = 2\,\text{M P}$$

$$\text{Area of cycloid E A F} = \tfrac{3}{4}\pi\,\text{A B}^2$$

= 3 times area of generating circle.

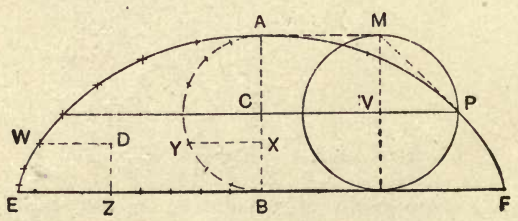


Fig. 5.

MENSURATION.

Method of Describing the Cycloid.—Let E F be the line upon which the circle (centre V.) rolls. E F = length of circumference.

Divide off the circumference into a number of equal parts, as shown dotted, and, of course, divide E F into the same number. Take the third division point Z (from E). Erect a vertical Z D at Z, so that Z D = height of third division point Y, of circle above E B F. Through D draw a line parallel to E B F, and mark off D W = Y X. Then W is a point on the curve.

Prism.—Volume = area of end × length.

Cylinder.—Length, l; diameter, d.

Area of curved surface $= \pi d l$

Area of whole surface $= \pi d l + \frac{\pi d^2}{2}$

Volume of cylinder $= \frac{\pi}{4} d^2 l.$

Cone.—Height, h; radius of base, r; length of slant slide, l.

Area of curved surface of a right circular cone

$$= \pi r l \text{ or } \pi r \sqrt{h^2 + r^2}$$

Total area of surface of right circular cone

$$= \pi r \left(l + r \right) = \pi r \sqrt{h^2 + r^2} + \pi r^2$$

Area of curved surface of frustrum of a right circular cone

$$= \pi l (R + r)$$

where R and r are the radii of the circular ends respectively, and

l = the slant side of the frustrum.

Volume of cone = $\frac{1}{3}$ area of base × height.

= $\frac{1}{3}$ volume of circumscribing cylinder.

Volume of frustrum of cone $= \frac{1}{3} \pi h \frac{R^3 - r^3}{R - r}$

$$= \frac{1}{3} \pi h (R^2 + Rr + r^2)$$

Where h is the perpendicular height of the frustrum, R and r the respective radii of the ends of the frustrum.

MENSURATION.

Pyramid.—Volume = $\frac{1}{3}$ area of base $\times$ height.

Volume of frustrum of pyramid = $\frac{1}{3}$ height $(A + a + \sqrt{aA})$

Where A and a are the areas of the ends respectively.

Sphere.—Area of surface of sphere of radius r

$= 4 \pi r^2$

= 4 times area of diametral section.

= $\frac{2}{3}$ area of circumscribed cylinder.

Area of the surface of a zone of a sphere = area of corresponding zone of cylinder, thus (Fig. 6) :—

$\pi = \frac{22}{7}$ or 3·14159

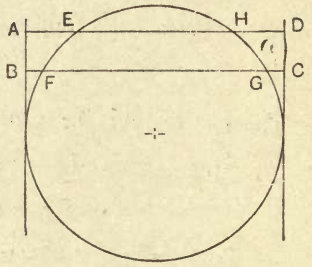


Fig. 6.

Area of zone E F G H = area of zone A B C D

Volume of a sphere = $\frac{4}{3} \pi r^3$.

= $\frac{2}{3}$ volume of circumscribing cylinder.

Volume of the frustrum of a sphere

$$= \pi r^2 \left(k \mp h \right) - \frac{\pi}{3} \left(k^3 \mp h^3 \right)$$

Where r is the radius of the sphere, k the distance of its outer face from centre and h the distance of its inner face from the centre, the upper sign is used if both faces are on the same side of the centre, and the lower sign if on opposite side of the centre.

MENSURATION.

Circle.—Length of circumference $= \pi \times$ diameter. $\pi = \frac{22}{7}$.

Area of circle $= \pi \times$ square of radius $= \frac{\pi}{4} \times$ square of diameter.

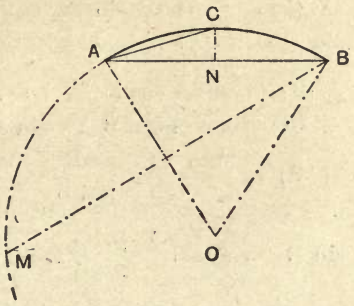


Fig. 7.

Length of arc A B C = B O $\times$ circular measure of the angle A O B.

Area of segment A B C =

$$= \frac{r}{2}\left(\text{arc A C B} - \text{B E}\right)$$

B E is the half chord of the double arc B C A M, and r is the radius of the circle.

If the segment is greater than a semi-circle the above negative sign is changed to positive.

The above area of segment may be expressed as

$$\frac{r^2}{2}\left(\theta - \text{Sin}\,\theta\right)$$

θ being the circular measure of the angle A O B subtended by the arc of segment.

The relation between the height C N $= h$ of the segment, the radius of the circle r, and the length of the chord A B $= c$ is

$$r = \frac{c^2 + 4h^2}{8h}$$

$$\text{and } c = 2\sqrt{2rh - h^2}$$

If the chord A C $= m$ of the semi-arc to be given, then

$$r = \frac{m^2}{2h}.$$

Ellipse.—Area $= \pi a b$, where a and b are the principal semi-axes

Volume of an ellipsoid $= \pi a b c$ where a b and c are the three semi-principal axes respectivelv

MATHEMATICAL DATA.

$$\sin^2 A + \cos^2 A = 1$$
$$1 + \tan^2 A = \sec^2 A$$
$$1 + \cot^2 A = \operatorname{cosec}^2 A$$
$$\sin(180° - A) = \sin A$$
$$\sin(90° - A) = \cos A$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

$$\sin A + \sin B = 2 \sin \frac{A+B}{2} \cdot \cos \frac{A-B}{2}$$
$$\sin A - \sin B = 2 \cos \frac{A+B}{2} \cdot \sin \frac{A-B}{2}$$
$$\cos A + \cos B = 2 \cos \frac{A+B}{2} \cdot \cos \frac{A-B}{2}$$
$$\cos A - \cos B = -2 \sin \frac{A+B}{2} \cdot \sin \frac{A-B}{2}$$

$$\sin 2A = 2 \sin A \cos A$$
$$\cos 2A = \cos^2 A - \sin^2 A$$
$$= 2 \cos^2 A - 1$$
$$= 1 - 2 \sin^2 A$$
$$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$$

$$\tan^2 A = \frac{1 - \cos 2A}{1 + \cos 2A}$$
$$\sin 3A = 3 \sin A - 4 \sin^3 A$$
$$\cos 3A = 4 \cos^3 A - 3 \cos A$$
$$\tan 3A = \frac{3 \tan A - \tan^3 A}{1 - 3 \tan^2 A}$$

$$\sin A = \pm \sqrt{\frac{1 - \cos 2A}{2}}$$

$$\cos A = \pm \sqrt{\frac{1 + \cos 2A}{2}}$$

$$2 \sin A = \pm \sqrt{1 + \sin 2A} \mp \sqrt{1 - \sin 2A}$$

$$2 \cos A = \pm \sqrt{1 + \sin 2A} \pm \sqrt{1 - \sin 2A}$$

MATHEMATICAL DATA.

Simple Relations Between the Sides and Angles of a Triangle.—Using the ordinary nomenclature, in which the side of the triangle *opposite* a given angle is represented by the same symbol in italics as that which represents the angle in Roman characters.

$$a = b \cos C + c \cos B$$
$$b = c \cos A + a \cos C$$
$$c = a \cos B + b \cos A.$$

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2\,b\,c}$$
$$\cos B = \frac{c^2 + a^2 - b^2}{2\,a\,c}$$
$$\cos C = \frac{a^2 + b^2 - c^2}{2\,a\,b}$$

$$\sin (A + B) = \sin C.$$
$$\cos (A + B) = -\cos C.$$
$$\sin \frac{A + B}{2} = \cos \frac{C}{2}.$$
$$\tan \frac{A + B}{2} = \cot \frac{C}{2}.$$
$$\tan \frac{A - B}{2} = \frac{a - b}{a + b} \cdot \cot \frac{C}{2}$$

$$\text{If } s = \frac{a + b + c}{2} \text{ then}$$
$$\sin \frac{A}{2} = \sqrt{\frac{(s - b)(s - c)}{bc}}$$
$$\cos \frac{A}{2} = \sqrt{\frac{s(s - a)}{bc}}$$

Area of a triangle = S

$$= \frac{1}{2}\, a\, b \sin C$$
$$= \frac{1}{2}\, b\, c \sin A$$
$$= \frac{1}{2}\, c\, a \sin B$$
$$= \sqrt{s(s - a)(s - b)(s - c)}$$

MATHEMATICAL DATA.

Area of a regular polygon of n sides the length of each of which is L.

$$= \frac{n\,L^2}{4} \cot \frac{\pi}{n}$$

The radius R of a circle described about a triangle

$$= \frac{a}{2 \sin A} = \frac{b}{2 \sin B} = \frac{c}{2 \sin C}$$

$$= \frac{a.b.c.}{4\,S}$$

$$= \frac{a\,b\,c}{4\sqrt{s\,(s-a)\,(s-b)\,(s-c)}}.$$

For odd values of n

$$2^{n-1}\left(-1\right)^{\frac{n-1}{2}} \sin^n \theta = \sin n\,\theta - n \sin (n-2)\,\theta$$

$$+ \frac{n\,(n-1)}{1 \cdot 2} \sin (n-4)\,\theta$$

$$- + \ldots \left(-1\right)^{\frac{n-1}{2}} \frac{n\ (n-1) \ldots \frac{1}{2}\ (n-3)}{\left|\frac{n-1}{2}\right.} \sin \theta$$

For even values of n

$$2^{n-1}\left(-1\right)^{\frac{n}{2}} \sin^n \theta = \cos n\,\theta - n \cos (n-2)\,\theta$$

$$+ \frac{n\,(n-1)}{1 \cdot 2} \cos (n-4)\,\theta$$

$$- + \ldots \frac{\left(-1\right)^{\frac{n}{2}} n\,(n-1) \ldots (\tfrac{1}{2}n+1)}{2 \cdot 1 \cdot 2 \cdot 3 \ldots \frac{n}{2}}$$

MATHEMATICAL DATA.

Series.—

$$1+2+3+4+\&c.+n=\frac{n(n+1)}{2}$$

$$1^2+2^2+3^2+4^2+\&c.+n^2=\frac{n(n+1)(2n+1)}{6}$$

$$1^3+2^3+3^3+4^3+\&c.+n^3=\left\{\frac{n(n+1)}{2}\right\}^2$$

Arithmetical Series, common difference d, number of terms n, first term a.

$$\text{Sum of } n \text{ terms} = \frac{n}{2}\left\{2a+(n-1)d\right\}$$

Geometrical Series, common factor r.

$$\text{Sum of } n \text{ terms} = \frac{a(r^n-1)}{r-1}$$

Binomial Series.—

$$(x+y)^n = x^n + n\,x^{n-1}y + \frac{n(n-1)}{1\cdot 2}x^{n-2}y^2 + \frac{n(n-1)(n-2)}{1\cdot 2\cdot 3}x^{n-3}y^3 + \text{etc.}$$

Logarithmic Series.—

$$a^x = 1 + x\log_e a + \frac{x^2(\log_e a)^2}{\lfloor 2} + \frac{x^3(\log_e a)^3}{\lfloor 3} + \text{etc.}$$

$$e^x = 1 + x + \frac{x^2}{\lfloor 2} + \frac{x^3}{\lfloor 3} + \frac{x^4}{\lfloor 4} + \text{to infinity.}$$

$$e = 1 + 1 + \frac{1}{\lfloor 2} + \frac{1}{\lfloor 3} + \frac{1}{\lfloor 4} + \frac{1}{\lfloor 5} + \text{to infinity.}$$

$$\log_e a = (a-1) - \frac{1}{2}(a-1)^2 + \frac{1}{3}(a-1)^3 - \frac{1}{4}(a-1)^4 + \text{to infinity.}$$

$$\log_e(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \text{to infinity.}$$

$$\log_e(1-x) = -x - \frac{x^2}{2} - \frac{x^3}{3} - \frac{x^4}{4} - \text{to infinity.}$$

$$\log_e\frac{1+x}{1-x} = 2\left[x + \frac{x^3}{3} + \frac{x^5}{5} + \frac{x^7}{7} + \text{etc.}\right]$$

$$\log_e\frac{m}{n} = 2\left[\frac{m-n}{m+n} + \frac{1}{3}\left(\frac{m-n}{m+n}\right)^3 + \frac{1}{5}\left(\frac{m-n}{m+n}\right)^5 + \text{etc.}\right]$$

$$\log_e x = 2\left[\frac{x-1}{x+1} + \frac{1}{3}\left(\frac{x-1}{x+1}\right)^3 + \frac{1}{5}\left(\frac{x-1}{x+1}\right)^5 + \text{etc.}\right]$$

TRIGONOMETRICAL SERIES.

$$\sin a + \sin(a+\beta) + \sin(a+2\beta) + \text{etc. to } n \text{ terms}$$

$$= \frac{\sin\left(a + \frac{n-1}{2}\beta\right)\sin\frac{n\beta}{2}}{\sin\frac{\beta}{2}}$$

$$\cos a + \cos(a+\beta) + \cos(a+2\beta) + \text{etc. to } n \text{ terms}$$

$$= \frac{\cos\left(a + \frac{n-1}{2}\beta\right)\cos\frac{n\beta}{2}}{\sin\frac{\beta}{2}}$$

$$\sin x = x - \frac{x^3}{\lfloor 3} + \frac{x^5}{\lfloor 5} - \frac{x^7}{\lfloor 7} + \text{etc. to infinity.}$$

$$\cos x = 1 - \frac{x^2}{\lfloor 2} + \frac{x^4}{\lfloor 4} - \frac{x^6}{\lfloor 6} + \text{etc.}$$

$$\tan x = x + \frac{x^2}{3} + \frac{2}{15}x^5 + \text{etc.}$$

$$\sin x = \frac{e^{x\sqrt{(-1)}} - e^{-x\sqrt{(-1)}}}{2\sqrt{(-1)}}$$

$$\cos x = \frac{e^{x\sqrt{(-1)}} + e^{-x\sqrt{(-1)}}}{2}$$

$$\sin^{-1} x = x + \frac{1}{2\cdot 3}x^3 + \frac{1\cdot 3}{2\cdot 4\cdot 5}x^5 + \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6\cdot 7}x + \text{etc.}$$

$$\cos^{-1} x = \frac{\pi}{2} - \sin^{-1} x.$$

$$\tan^{-1} x = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \text{etc.}$$

HYPERBOLIC FUNCTIONS.

$$\sinh x = \frac{1}{\operatorname{cosech} x} = \frac{e^x - e^{-x}}{2} = -\sqrt{-1}\sin x\sqrt{-1}$$

$$\cosh x = \frac{1}{\operatorname{sech} x} = \frac{e + e^{-x}}{2} = \cos x\sqrt{-1}$$

$$\tanh x = \frac{1}{\coth x} = \frac{\sinh x}{\cosh x} = \frac{e^{2x} - 1}{e^{2x} + 1}$$

$$\sinh^{-1}\frac{x}{a} = \log_e\left(\frac{x + \sqrt{x^2 + a^2}}{a}\right)$$

$$\cosh^{-1}\frac{x}{a} = \log_e\left(\frac{x + \sqrt{x^2 - a^2}}{a}\right)$$

$$\tanh^{-1}\frac{x}{a} = \tfrac{1}{2}\log_e\frac{a + x}{a - x}$$

$$\coth^{-1}\frac{x}{a} = \tfrac{1}{2}\log_e\frac{x + a}{x - a}$$

$$\operatorname{sech}^{-1}\frac{x}{a} = \log_e\left(\frac{a}{x} + \sqrt{\frac{a^2}{x^2} - 1}\right)$$

$$\operatorname{cosech}^{-1}\frac{x}{a} = \log_e\left(\frac{a}{x} + \sqrt{\frac{a^2}{x^2} + 1}\right)$$

$$\cosh^2 x + \sinh^2 x = \cosh 2x$$

$$\operatorname{sech}^2 x + \tanh^2 x = 1$$

$$2\sinh x\cosh x = \sinh 2x$$

$$\cosh^2 x - \sinh^2 x = 1$$

$$\operatorname{cosech}^2 x = \coth^2 x - 1$$

STANDARD DIFFERENTIAL COEFFICIENTS.

$$d.\ x^n = n\,x^{n-1}\,dx$$

$$d\log_e x = \frac{1}{x}dx$$

$$d\log_a x = \frac{1}{x}\log_a e\,dx = \frac{1}{x\log_e a}\,.\,dx$$

$$d.\ e^x = e^x\,dx$$

$$d.\ a^x = a^x \log^e a.\ dx$$

$d.\ \sin x$	$= \cos x.\ dx.$	$d.\ \sinh x$	$= \cosh x.\ \mathrm{dx}.$
$d.\ \cos x$	$= -\sin x.\ dx.$	$d.\ \cosh x$	$= \sinh x.\ dx.$
$d.\ \tan x$	$= \sec^2 x.\ dx$	$d.\ \tanh x$	$= \mathrm{sech}^2 x.\ dx.$
$d.\ \cot x$	$= -\mathrm{cosec}^2 x.\ dx.$	$d.\ \coth x$	$= -\mathrm{cosech}^2 x.\ dx.$
$d.\ \sec x$	$= \sec x.\ \tan x.\ dx.$	$d.\ \mathrm{sech}\ x$	$= -\mathrm{sech}\ x.\ \tanh x.\ dx.$
$d.\ \mathrm{cosec}\ x$	$= -\mathrm{cosec}\ x \cot x.\ dx.$	$d.\ \mathrm{cosech}\ x$	$= -\mathrm{cosech}\ x.\ \coth x.\ dx.$

$$d\sin^{-1} x = \frac{1}{\sqrt{1-x^2}}\,.\,dx$$

$$d\cos^{-1} x = \frac{-1}{\sqrt{1-x^2}}\,.\,dx$$

$$d\tan^{-1} x = \frac{1}{1+x^2}\,.\,dx$$

$$d\cot^{-1} x = \frac{-1}{1+x^2}\,.\,dx$$

$$d\sec^{-1} x = \frac{1}{x\sqrt{x^2-1}}\,.\,dx$$

$$d\,\mathrm{cosec}^{-1} x = \frac{-1}{x\sqrt{x^2-1}}\,.\,dx$$

STANDARD INTEGRALS.

$$\int x^n \,.\, dx. = \frac{x^{n+1}}{n+1}$$

$$\int e^x \,.\, dx = e^x$$

$$\int a^x \,.\, dx = \frac{a^x}{\log_e a}$$

$$\int \frac{dx}{x} = \log_e x$$

$$\int \log_e x.\, dx = x\left(\log_e x - 1\right) = x \log_e \left(\frac{x}{e}\right)$$

$$\int x \log x = \frac{x^2}{2}\left(\log_e x - \frac{1}{2}\right)$$

$$\int \sin x.\, dx. = -\cos x$$

$$\int \cos x.\, dx. = \sin x.$$

$$\int \tan x.\, dx = \log \sec. x. = -\log \cos x.$$

$$\int \cot x.\, dx = \log \sin x = -\log \operatorname{cosec} x.$$

$$\int \sec x.\, dx = \log \tan \left(\frac{\pi}{4} + \frac{x}{2}\right) = \log. \cot \left(\frac{\pi}{4} - \frac{x}{2}\right)$$

$$\int \operatorname{cosec} x.\, dx = \log \tan \frac{x}{2}$$

$$\int \sin^2 x.\, dx = \frac{x}{2} - \frac{\sin 2x}{4}$$

$$\int \cos^2 x.\, dx = \frac{x}{2} + \frac{\sin 2x}{4}$$

$$\int \tan^2 x.\, dx = \tan x - x.$$

$$\int \cot^2 x.\, dx = -\cot x - x.$$

$$\int \sec^2 x.\, dx = \tan x.$$

$$\int \operatorname{cosec}^2 x.\, dx = -\cot x.$$

STANDARD INTEGRALS.

$$\int \sec x . \tan x . dx = \int \frac{\sin x}{\cos^2 x} dx. = \sec x.$$

$$\int \operatorname{cosec} x . \cot x . dx = \int \frac{\cos x}{\sin^2 x} d x = - \operatorname{cosec} x.$$

$$\int \frac{d x}{\sqrt{a^2 - x^2}} = \sin^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{\sqrt{x^2 + a^2}} = \sinh^{-1} \frac{x}{a} = \log_e [x + \sqrt{x^2 + a^2}]$$

$$\int \frac{- d x}{\sqrt{a^2 - x^2}} = \cos^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{\sqrt{x^2 - a^2}} = \cosh^{-1} \frac{x}{a} = \log_e \frac{[x + \sqrt{x^2 - a^2}]}{a}$$

$$\int \frac{d x}{a^2 + x^2} = \frac{1}{a} \tan^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{a^2 - x^2} = \frac{1}{a} \tanh^{-1} \frac{x}{a} = \frac{1}{2 a} \log_e \frac{a + x}{a - x}$$

$$\int \frac{- d x}{a^2 + x^2} = \frac{1}{a} \cot^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{x^2 - a^2} = - \frac{1}{a} \coth^{-1} \frac{x}{a} = \frac{1}{2 a} \log_e \frac{x - a}{x + a}$$

$$\int \frac{d x}{x \sqrt{x^2 - a^2}} = \frac{1}{a} \sec^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{x \sqrt{a^2 - x^2}} = - \frac{1}{a} \operatorname{sech}^{-1} \frac{x}{a} = - \frac{1}{a} \log_e \left(\frac{a}{x} + \sqrt{\frac{a^2}{x^2} - 1} \right)$$

$$\int \frac{- d x}{x \sqrt{x^2 - a^2}} = \frac{1}{a} \operatorname{cosec}^{-1} \frac{x}{a}.$$

$$\int \frac{d x}{x \sqrt{a^2 + x^2}} = \frac{1}{a} \operatorname{cosech}^{-1} \frac{x}{a} = - \frac{1}{a} \log_e \left(\frac{x}{a} + \sqrt{\frac{x^2}{x^2} + 1} \right)$$

STANDARD INTEGRALS.

$$\int \frac{dx}{\sqrt{2ax - x^2}} = \text{vers}^{-1}\frac{x}{a} \qquad \int \frac{c\,dx}{\sqrt{x^2 - 2cx}} = \log_e \frac{x + c + \sqrt{x^2 - 2cx}}{c.}$$

$$\int \frac{-dx}{\sqrt{2ax - x^2}} = \text{covers}^{-1}\frac{x}{a} \qquad \int \frac{c\,dx}{\sqrt{x^2 + 2cx}} = \log_e \frac{x + c + \sqrt{x^2 + 2cx}}{c.}$$

$$\int \frac{dx}{(x-a)\,(x-b)} = \frac{1}{a-b} \log_e \frac{x-a}{x-b.}$$

$$\int \frac{dx}{\sqrt{a+x}\,\sqrt{b+x}} = 2 \log_e \left(\sqrt{a+x} + \sqrt{b+x}\right)$$

$$\int \frac{1}{\sqrt{(x+a)\,(b-x)}}\, dx = 2 \sin^{-1}\sqrt{\frac{x+a}{a+b}}$$

$$\int \sqrt{a^2 - x^2}\, dx = \frac{x}{2}\sqrt{a^2 - x^2} + \frac{a^2}{2} \sin^{-1}\frac{x}{a.}$$

$$\int \sqrt{x^2 \pm a^2}\, dx = \frac{x}{2}\sqrt{x^2 \pm a^2} \pm \frac{a^2}{2} \log_e \left(\frac{x + \sqrt{x^2 \pm a^2}}{a}\right)$$

$$\int e^{ax} \sin bx.\, dx = \frac{e^{ax}}{\sqrt{a^2 + b^2}} \cdot \sin\left(bx - \tan^{-1}\frac{b}{a}\right)$$

$$\int e^{ax} \cos bx.\, dx = \frac{e^{ax}}{\sqrt{a^2 + b^2}} \cos\left(bx - \tan^{-1}\frac{b}{a}\right)$$

$$\int \frac{1}{ax^2 + bx + c}\, dx = \frac{1}{\sqrt{b^2 - 4ac}} \log_e \frac{2ax + b - \sqrt{b^2 - 4ac}}{2ax + b + \sqrt{b^2 - 4ac}}$$

$$\text{or} = \frac{2}{\sqrt{4ac - b^2}} \tan^{-1}\frac{2ax + b}{\sqrt{4ac - b^2}}$$

according as b^2 is greater than or less than $4ac$.

$$\int \sin^{2n+1} x\, dx = -\cos x + n\frac{\cos^3 x}{3} - \frac{n(n-1)}{1\cdot 2}\frac{\cos^5 x}{5}$$

$$+ \frac{n(n-)(n-2}{1\cdot 2\cdot 3}\frac{\cos^7 x}{7} - + \ldots - (-1)^n \frac{\cos^{2n+1} x}{2n+1}$$

Similarly,

$$\int \cos^{2n+1} x\, dx = \sin x - n\frac{\sin^3 x}{3} + \frac{n.(n-1)}{1\cdot 2}\frac{\sin^5 x}{5} - \ldots + (-1)^n \frac{\sin^{2n+1} x}{2n+1}$$

$$\int_0^{\frac{\pi}{2}} \sin^n x\, dx = \int_0^{\frac{\pi}{2}} \cos^n x\, dx = \frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdot\frac{n-5}{n-4}\cdots\frac{3}{4}\cdot\frac{1}{2}\cdot\frac{\pi}{2}$$

when n is an even number, but

$$= \frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdot\frac{n-5}{n-4}\cdots\frac{4}{5}\cdot\frac{2}{3}$$

when n is an odd number.

DIFFERENTIAL EQUATIONS.

Equation I.

$$\frac{d^2y}{dx^2} = K_1 . + K_2x + K_3x^2 + \ . \ . \ . \ K_{n-1}x^{n-2}$$

Solution :—

$$y = K + K_0x + K_1\frac{x^2}{2\cdot1} + K_2\cdot\frac{x_3}{3\cdot2} + K_3\cdot\frac{x^4}{4\cdot3} + \ . \ . + K_{n-1}\cdot\frac{x^n}{n\,(n-1)}$$

where K and K_0 are constants of integration.

This equation comes in the theory of the deflection of beams.

Equation II.

$$\frac{d^2y}{dx^2} = \pm Ky.$$

Solution (1).—

With the lower sign and $i = \sqrt{-1}$

$$y = A\,e^{ix\sqrt{K}} + B\,e^{-ix\sqrt{K}}$$

or

$$y = C \sin x\sqrt{K} + D \cos x\sqrt{K}$$

Where A, B C, and D are constants of integration.

This is the equation for the oscillations of a pendulum or spring, undamped. It is also used in the theory of struts.

Solution (2).—

With the upper sign :—

$$y = E\,e^{x\sqrt{K}} + F\,e^{-x\sqrt{K}}$$

Note that if $y = o$ when $x =$ infinity, then $A = o$.

This equation is used in connection with a badly insulated cable carrying current, or bar conducting heat, when of small cross section, in the steady state.

Equation III. (for damped oscillations).

$$\frac{d^2y}{dx^2} + K\frac{dy}{dx} + K_1\,y = o$$

K and K_1 being constants.

The solution is obtained by putting

$$y = \mathrm{A}\, e^{ax}$$

differentiating twice and substituting in the first term of above equation, and substituting the first differential coefficient in the second term. Then we have

$$a^2 + \mathrm{K}a + \mathrm{K}_1 = o.$$

This gives *drifting* if the roots are *real*, that is, if

$$\mathrm{K}_1 < \frac{\mathrm{K}^2}{4}$$

and the solution is—

$$a = \frac{-\mathrm{K} \pm \sqrt{\mathrm{K}^2 - 4\mathrm{K}_1}}{2}$$

$$\text{and } y = \mathrm{A}\, e^{\frac{-\mathrm{K} + \sqrt{\mathrm{K}^2 - 4\mathrm{K}_1}}{2} x} + \mathrm{B}\, e^{\frac{-\mathrm{K} - \sqrt{\mathrm{K}^2 - 4\mathrm{K}_1}}{2} x}$$

$$= e^{\frac{-\mathrm{K}x}{2}} \left[\mathrm{A}\, e^{\frac{\sqrt{\mathrm{K}_2 - 4\mathrm{K}_1}}{2} x} + \mathrm{B}\, e^{\frac{-\sqrt{\mathrm{K}_2 - 4\mathrm{K}_1}}{2} x} \right]$$

Note that by suitably choosing the starting point we generally get

$$\mathrm{A} = -\mathrm{B}$$

If the roots are *imaginary* we get damped oscillations.

$$\text{When } \mathrm{K}_1 > \frac{\mathrm{K}^2}{4}$$

$$a = \frac{-\mathrm{K} \pm i\sqrt{4\mathrm{K}_1 - \mathrm{K}^2}}{2}$$

and

$$y = e^{\frac{-\mathrm{K}x}{2}} \left(\mathrm{C} \sin x \frac{\sqrt{4\mathrm{K}_1 - \mathrm{K}^2}}{2} + \mathrm{D} \cos x \frac{\sqrt{4\mathrm{K}_1 - \mathrm{K}^2}}{2} \right)$$

Note that by suitably choosing the starting point we can make either C or D $= o$.

If

$$\mathrm{K}_1 = \frac{\mathrm{K}^2}{4}$$

we get dead-beatness or so-called critical damping

$$a = \frac{-\mathrm{K}x}{2}$$

and there are two *equal* values for a.

The solution in this case is obtained by supposing that the roots differ by a small quantity h, which ultimately becomes zero, then

$$y = \left(\mathrm{A} + \mathrm{B}x\right) e^{\frac{-\mathrm{K}x}{2}}$$

where A and B are constants of integration. (See Forsyth's "Differential Equations," p. 53

Equation IV.—

$$\frac{d^2y}{dx^2} + K_1\frac{dy}{dx} + K_2y = K_3$$

Solution.—

$$y = \left(\text{solution as in III.}\right) + \frac{K_3}{K_2}$$

This equation is used where some movable body is acted upon by a controlling force and a *constant* disturbing force; wherever the motion cannot be expressed by equations II. or III.

Equation V.

$$\frac{d^2y}{dx^2} + K_1\frac{dy}{dx} + K_2y = \text{some function of } x.$$

Solution.—

y = (solution as in III.) + (any particular solution, usually obtained by guesswork, of complete equation).

Examples of V.—

(1) The discharge of a condenser through a too slightly weighted ballistic galvanometer

$$\frac{d^2y}{dx^2} + K_1\frac{dy}{dx} + K_2y = K_3\,e^{-mx}$$

Particular Solution.—

$$y = \frac{K_3}{m^2 - K_1m + K_2}e^{-mx}$$

which is obtained by trying

$$y = H\,e^{-mx}$$

(2) The behaviour of a galvanometer needle acted upon by an alternating current of low periodicity or of an engine indicator pencil

$$\frac{d^2y}{dx^2} + K_1\frac{dy}{dx} + K_2y = K_2 \sin px$$

Particular Solution.—

$$y = \frac{K_3}{(K_2 - p^2)^2 + (K_1p)^2}\left[(K_2 - p^2)\sin px - K_1\,p\cos px\right]$$

which is obtained by splitting up sin px into its exponential expression and proceeding as in last equation.

Instead of $K_3 \sin px$ we may have any periodic function of x, and split it up into sines and cosines by Fourier's theorem, proceeding then by above method.

(3) Action of alternating current of low periodicity on a Siemens dynamometer.

$$\frac{d^2y}{dx^2} + K_1 \frac{dy}{dx} + K_2 y = K_3 \sin^2 px.$$

Solution.—Proceed thus—

$$K_3 \sin^2 px = -\frac{K_3}{2}\left(1 - 2\sin^2 px\right) + \frac{K_3}{2}$$

$$= -\frac{K_3}{2}\cos 2px + \frac{K_3}{2}$$

Now, split up equation into two parts, and proceed as in examples 1 and 2.

Particular Solution.—

$$y = \frac{K_3}{[(K_2 - 4p^2)^2 + 2p^2 K_1^2]}\left\{2p K_1 \sin px - (K2 - 4p^2)\cos 2px\right\}$$

Equation VI.—

$$\frac{dy}{dx} = \frac{x}{\sqrt{a^2 + x^2}}$$

Solution.—

$$y = \sqrt{a^2 + x^2} + C$$

C is a constant of integration.

$$\frac{dy}{dx} = \frac{c}{\sqrt{x^2 + 2ax}}$$

Solution.—

$$y = c \log_e \frac{x + a + \sqrt{x^2 + 2ax}}{a} + A$$

A being a constant of integration.

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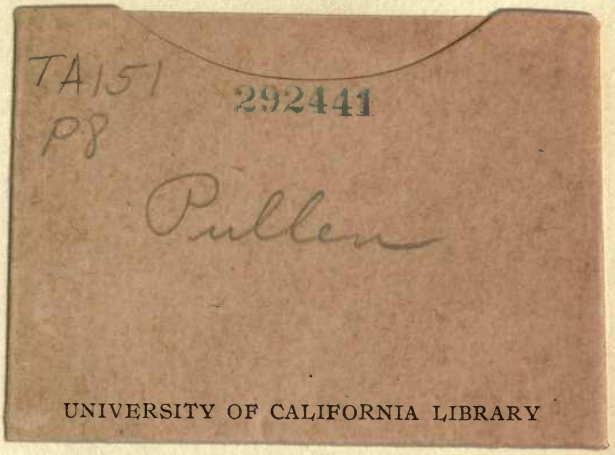
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